AFFDL-TM-79-40-FXN

AIR FORCE FLIGHT DYNAMICS LABORATORY
DIRECTOR OF LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT PATTERSON AIR FORCE BASE OHIO

IMPROVEMENT OF MODEL AXIAL CONTROL SYSTEM FOR ABLATION RATE TESTING OF MISSILE NOSE TIPS IN RENT FACILITY

Charles W. Wood

and

Henry D. Baust

FEBRUARY 1979

Approved for public release; distribution unlimited.

Experimental Engineering Branch
Aeromechanics Division
Air Force Flight Dynamics Laboratory
Wright-Patterson Air Force Base, Ohio 45433

NOTICES

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

This Technical Memorandum has been reviewed and is approved for publication.

Henry D. Baust

HENRY D. BAUST
Electronics Engr, Electronics Gp
Experimental Engineering Branch

Charles W. Wood

CHARLES W. WOOD
Electronic Tech, Electronics Gp
Experimental Engineering Branch

Robert G. Dunn

ROBERT G. DUNN
Chief, Experimental Engineering Br
Aeromechanics Division

Peter J. Butkewicz

PETER J. BUTKEWICZ, Col, USAF
Chief, Aeromechanics Division
Air Force Flight Dynamics Laboratory

ABSTRACT

This paper describes the functions, design and operation of the axial model positioning system for the Air Force Flight Dynamics Laboratory's Fifty Megawatt Re-Entry Nose Tip (RENT) Test Facility. This memorandum includes all improvements made to date. The axial model positioning system consists of five servo driven hydraulically operated model platforms which allow axial movement of the nose tip models. Several modes of operation are available including fixed position, heat sensor control and fixed velocity control.

This system has proven itself to be most valuable in maintaining the position of the nose tip of an ablating model within the test rhombus at the nozzle exit of the arc heated flow. It is also used to simulate flight conditions as a function of time, for a reentry flight path by use of the ramp mode.

FOREWORD

This report is the result of a continued effort to improve the efficiency and increase the capabilities of the 50 MW RENT Facility. The work was performed under Task 240413 "Aerodynamic Ground Test Technology", Work Unit 24041306 "Development of Unique Electronic Systems to Advance Aerodynamic Test Capability". The report was prepared by Charles W. Wood and Henry D. Baust of the Experimental Engineering Branch, Aeromechanics Division, Air Force Flight Dynamics Laboratory.

Special acknowledgement is extended to the following people in the Experimental Engineering Branch: Mr. Perie Pitts and Mr. Alan Blore, for the design of the heat sensor mechanics, dual potentiometer mounting and other mechanical modifications; Mr. Bob Ballard for the design and check out of the ramp generator; Mrs. Willa Scott for the typing of the rough drafts and Rita Kibler for typing the final report; and TSgt Paul Lindsey, A1C Joseph Fesi and Sgt Roger Crosley for preparation of the figures.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS (Continued)

LIST OF TABLES

LIST OF DATA SHEETS

SECTION I

INTRODUCTION

The Air Force Flight Dynamics Laboratory's Fifty Megawatt Re-Entry Test Facility (RENT) provides a means of experimentally studying the aerothermodynamics of high speed flight. The RENT axial model positioning system discussed in this report was developed to provide a variety of test modes to the facility by controlled and programmable axial positioning of the test models during the actual tests. One of the modes, utilizing a ramping technique, provides a means to simulate test conditions a reentry vehicle experiences, as a function of time, along its reentry path. Another useful mode provides means to keep an ablating nose tip continuously within the test rhombus at the exit of the nozzle as the ablation process changes the nose tip's shape.

The RENT axial model positioning system can be discussed in terms of several different subsystems. This memorandum describes each of these subsytems or sections in detail as well as providing a set of operating instructions in Appendix A. The axial model positioning system is a series of five servo driven hydraulically operated model platforms (see Figure 1) upon which are mounted the model struts. The nose tip models are mounted on the struts and injected into the flow in a lateral motion (see Figure 2). Each strut is moved laterally to the center of the arc heated flow and then is "pinned" or locked in place. The axial drive system is then activated to control axial model movement as predetermined by the aerodynamic test needs. The master control unit (see Figure 3) is located in the control room. There are several modes of operation and combinaations of modes such that precise axial control of the model may be obtained.

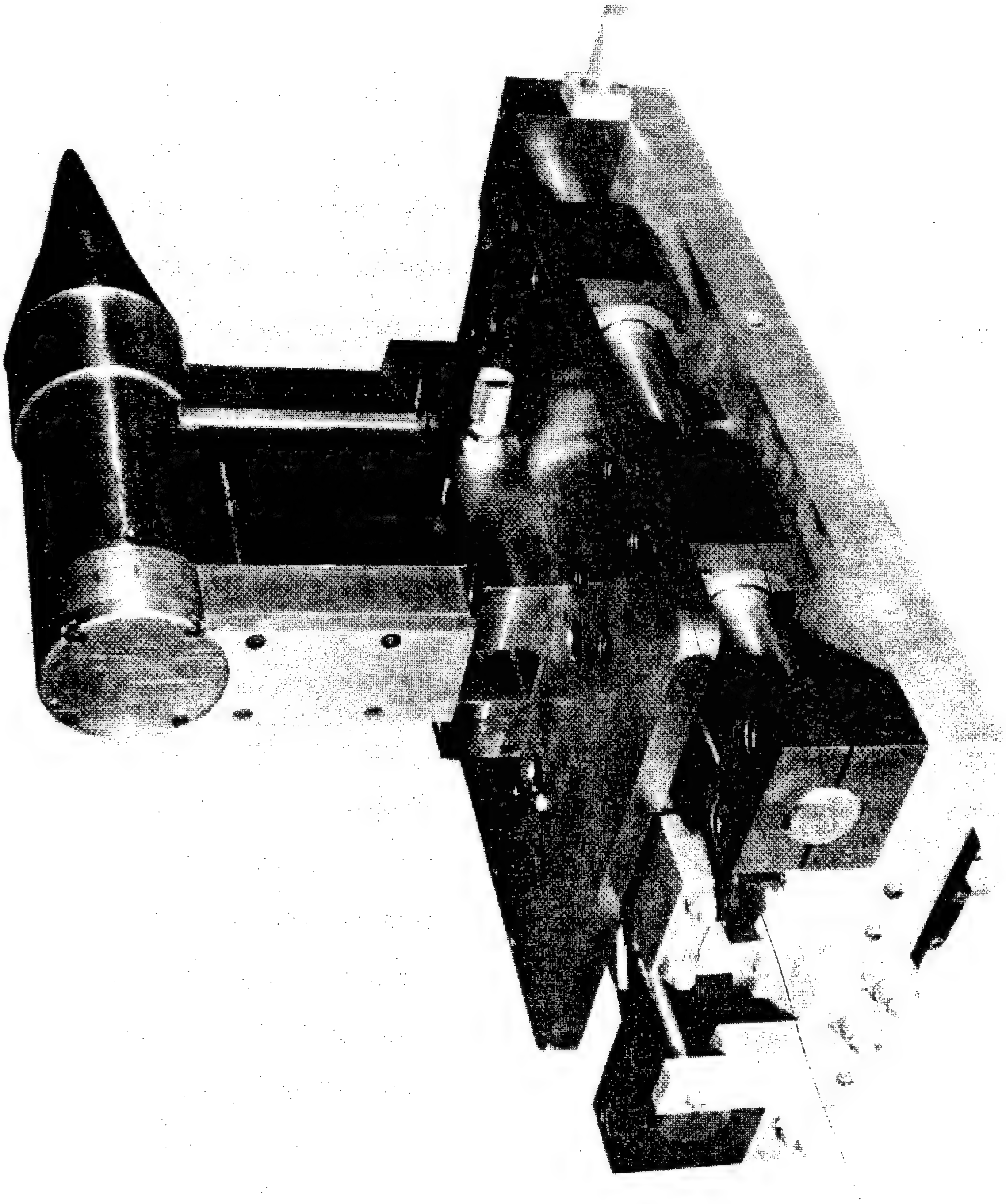


Figure 1 AXIAL DRIVE UNIT

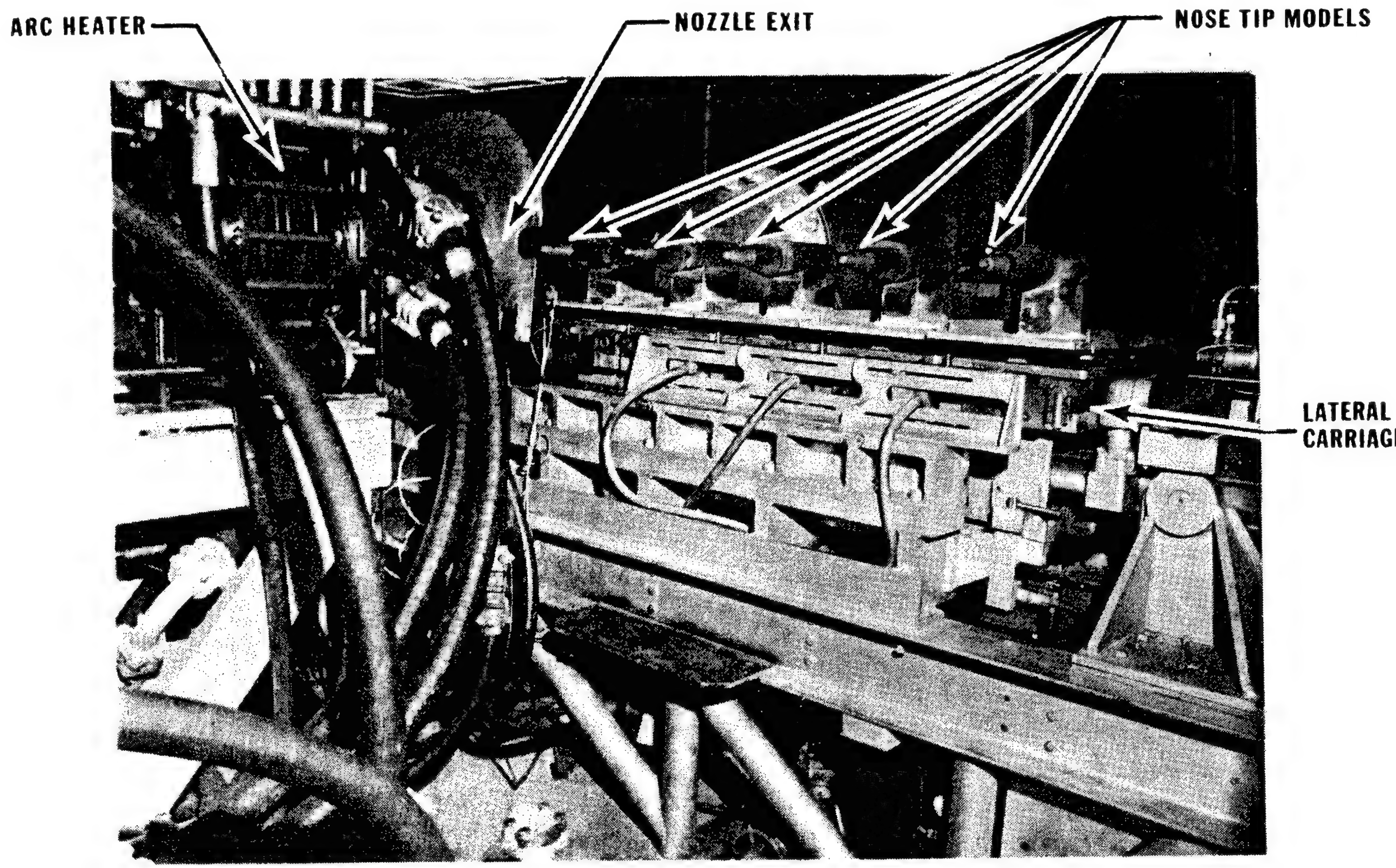


Figure 2 RENT MODEL CARRIAGE

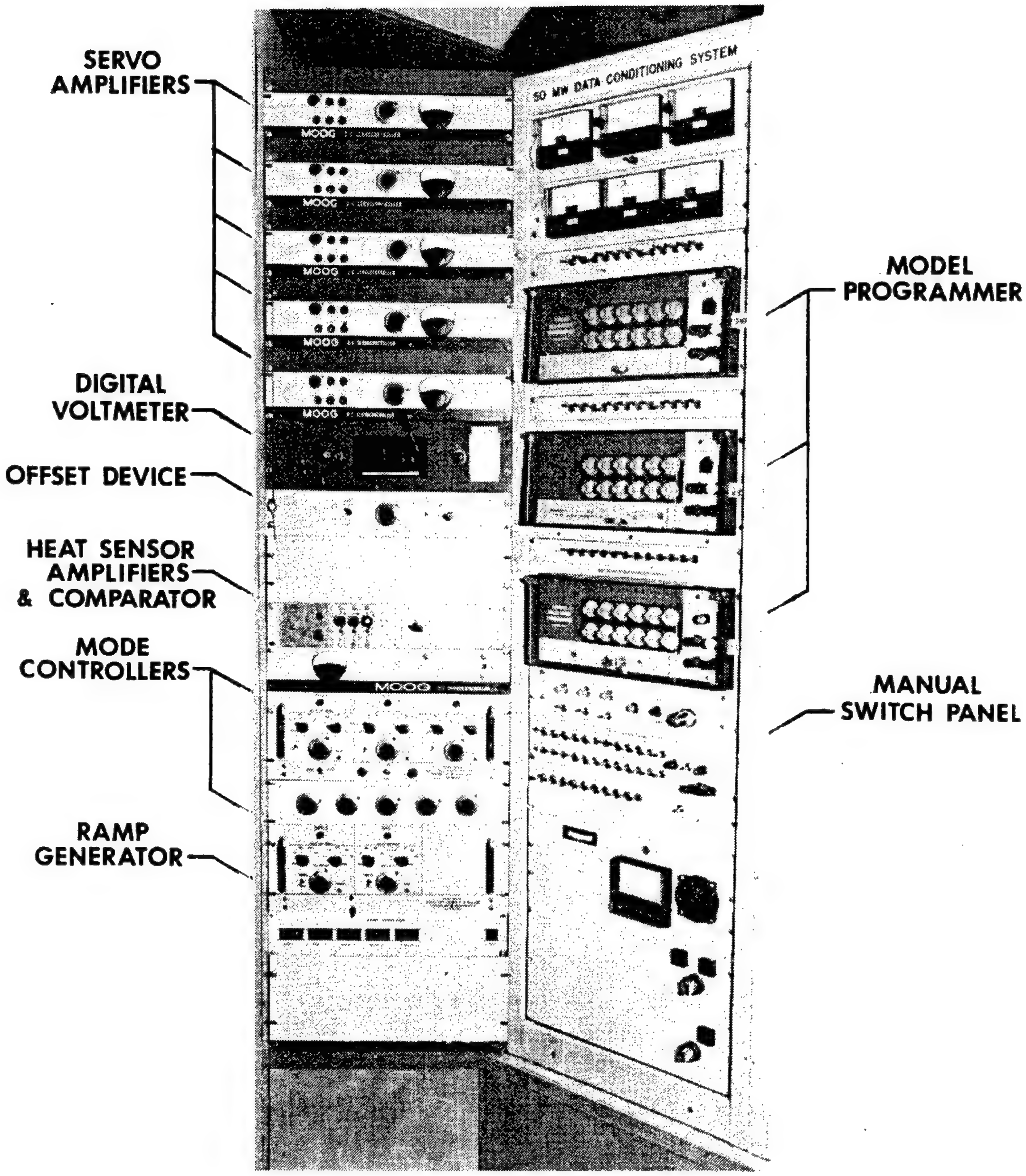


Figure 3 MASTER CONTROL UNIT

SECTION II

OPERATIONAL HAZARDS

The hydraulic servo mechanisms used for model positioning are capable of exerting large forces and may move at high rates of speed. Whenever there is hydraulic pressure present, the operator must make certain that the area is clear before operating the carriage and axial drive units. There is no way to make the system 100% safe as it must be "live" in order to perform routine model adjustments and calibrations. The operator must also guard against model damage which will occur if the carriage is moved past the arc heater nozzle when one or more of the axial drive units is too far forward.

SECTION III

FUNCTIONAL DESCRIPTION

For the discussion which follows, reference is made to the block diagram of Figure 4. For orientation of the reader the location of the component parts is as indicated by the dashed line, i.e., control room and RENT area.

There are two basic modes of operation of the axial positioning system. The first, the position mode of operation allows the model platform to be positioned at a fixed distance from the arc heater nozzle exit plan. This distance may be set by means of a panel mounted potentiometer. There are two fixed positions available both of which are adjustable. (Note: Position one and position two potentiometers and a related relay control illustrated in Figure 4.) Velocity control is also available to vary the axial speed. A ramp generator is used to obtain velocity control (See Appendix D).

The second basic mode of servo operation is by means of heat sensor control. Heat sensor control was designed to control the system operation when testing ablative models. During heat sensor mode of operation all position set components are switched out of the circuit by means of relays. The use of the term ablative models indicates that the model nose tip is ablating or burning away. The heat sensor mode of operation is used to keep the models within the testing rhombus of arc heater nozzle flow. This mode drives the models forward at a rate equal to the loss of material from the model nose tip due to ablation. This keeps it a fixed distance from the nozzle.

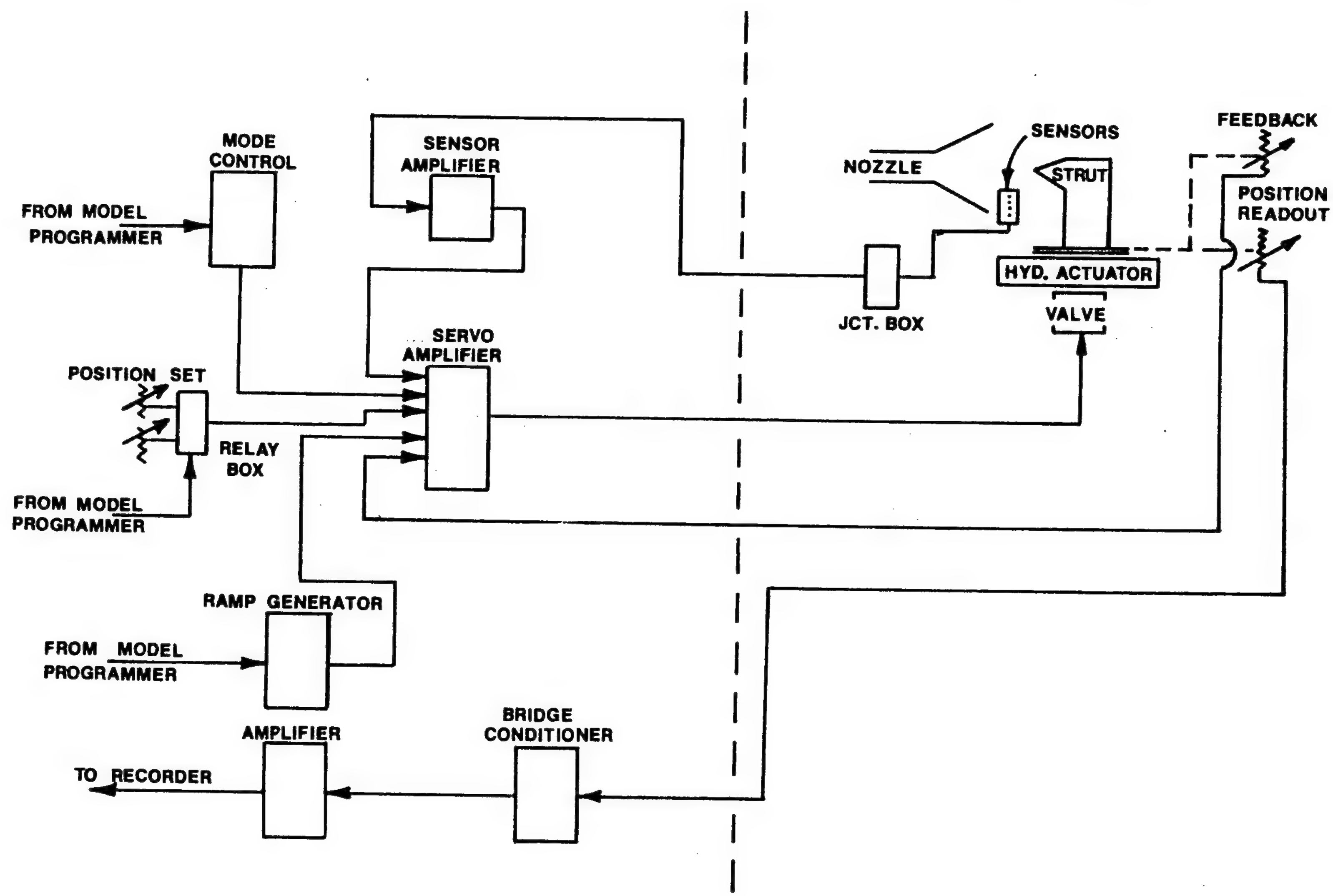


FIGURE 4: RENT AXIAL MODEL POSITIONING SYSTEM BLOCK DIAGRAM

The axial model platform may be moved a distance of six inches. The positioning of the model platform is readout by means of a linear potentiometer and indicated by means of a digital panel meter located at the model operator's station. This signal is also recorded by an oscillograph and computer.

The sequence of events of the axial model positioning system is controlled by means of a programmable timing unit. The model programmer serves a dual function in that it is used to direct the lateral carriage movement and also controls the various modes of the axial model positioning system. The model programmer consists of 3 timing units connected to operate in sequence. It provides 36 sequential time steps and 36 control switches. The control switches can control 120 volts, 60 Hz power only and may not be used to switch DC power directly. The following paragraphs will serve to acquaint the reader with a detailed description of the axial model positioning system and the various component parts. It should be noted that five servo systems are necessary as there are five model platforms.

SECTION IV

SERVO AMPLIFIER

The servo amplifier was purchased as an off the shelf item to drive the hydraulic servo valve. It was modified where necessary to fulfill the design criteria of the RENT Axial Positioning System. There are five servo amplifiers installed in the system, one on each of the five hydraulically operated model platforms. Air Force drawing number X70D4234 contains the complete schematic of the servo amplifier. For ease of inclusion in a memorandum of this size the servo amplifier schematic was divided into three drawings: Figure 5, input circuitry; Figure 6, main amplifier with dither card and Figure 7, the power supply. For the following discussion of the servo amplifier, note that the term forward movement will indicate a model platform movement toward the arc heater nozzle, and the term rearward will indicate a model platform movement away from the nozzle.

With the aid of Figure 5 note that operational amplifier, A1, is corrected in such a manner that the input configuration is single ended which means that all input signals must be with reference to ground. The negative input terminal of the operational amplifier is used to provide a summing junction. Negative feedback is also connected to the summing junction and is routed from the amplifier output by means of resistors R48, R51 and potentiometer R12. Potentiometer R12 is used to adjust the gain of the operational amplifier and capacitors C3 and C14 provide high frequency equalization of the feedback network. Potentiometer R6 (Bias adjustment) is used to correct for DC offset errors in both the operational amplifier and main servo amplifier. (consult the operating and maintenance section, Appendix A, of this manual for the proper method to be used when

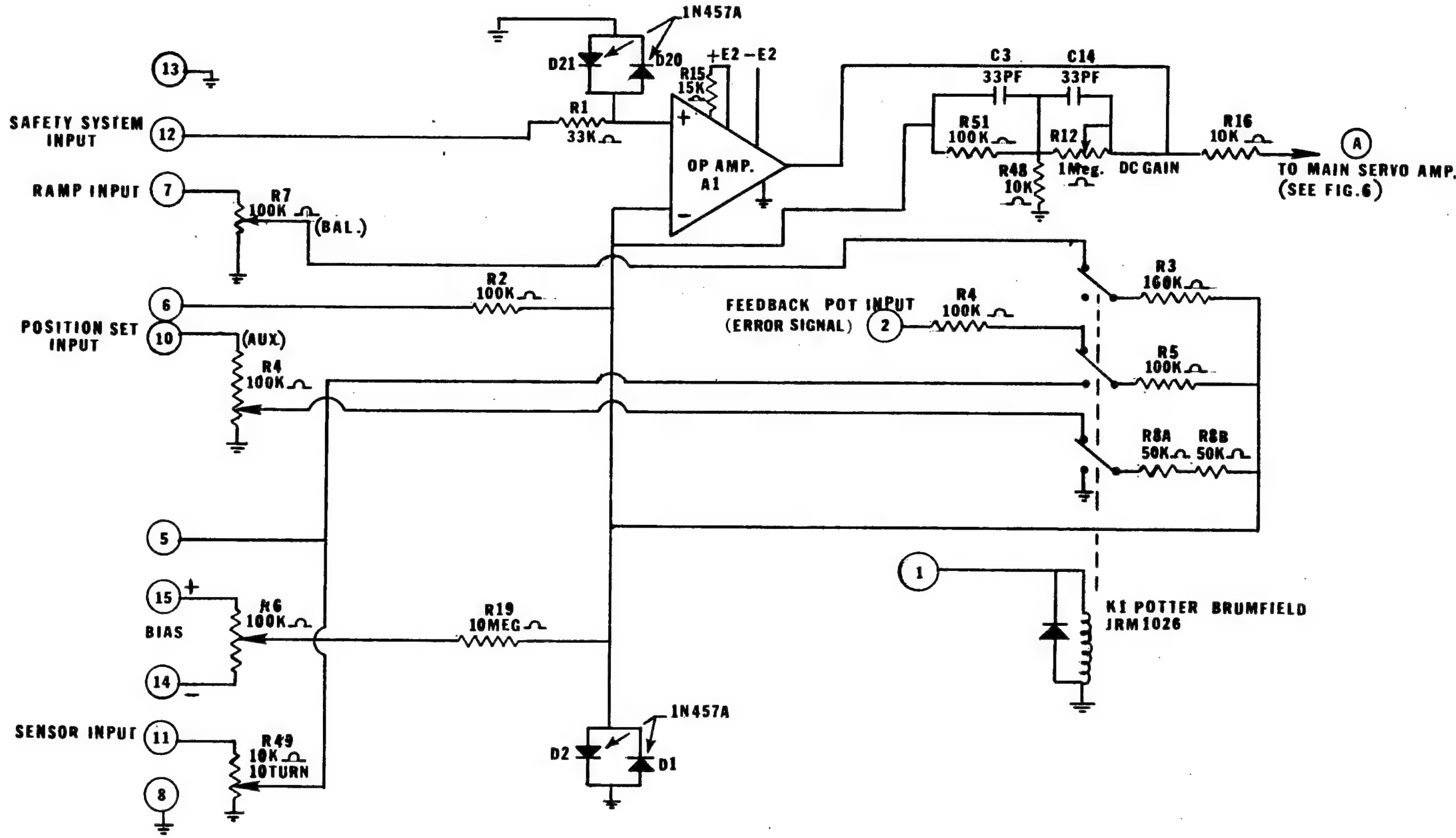


Figure 5 INPUT CIRCUIT FOR SERVO AMPLIFIER

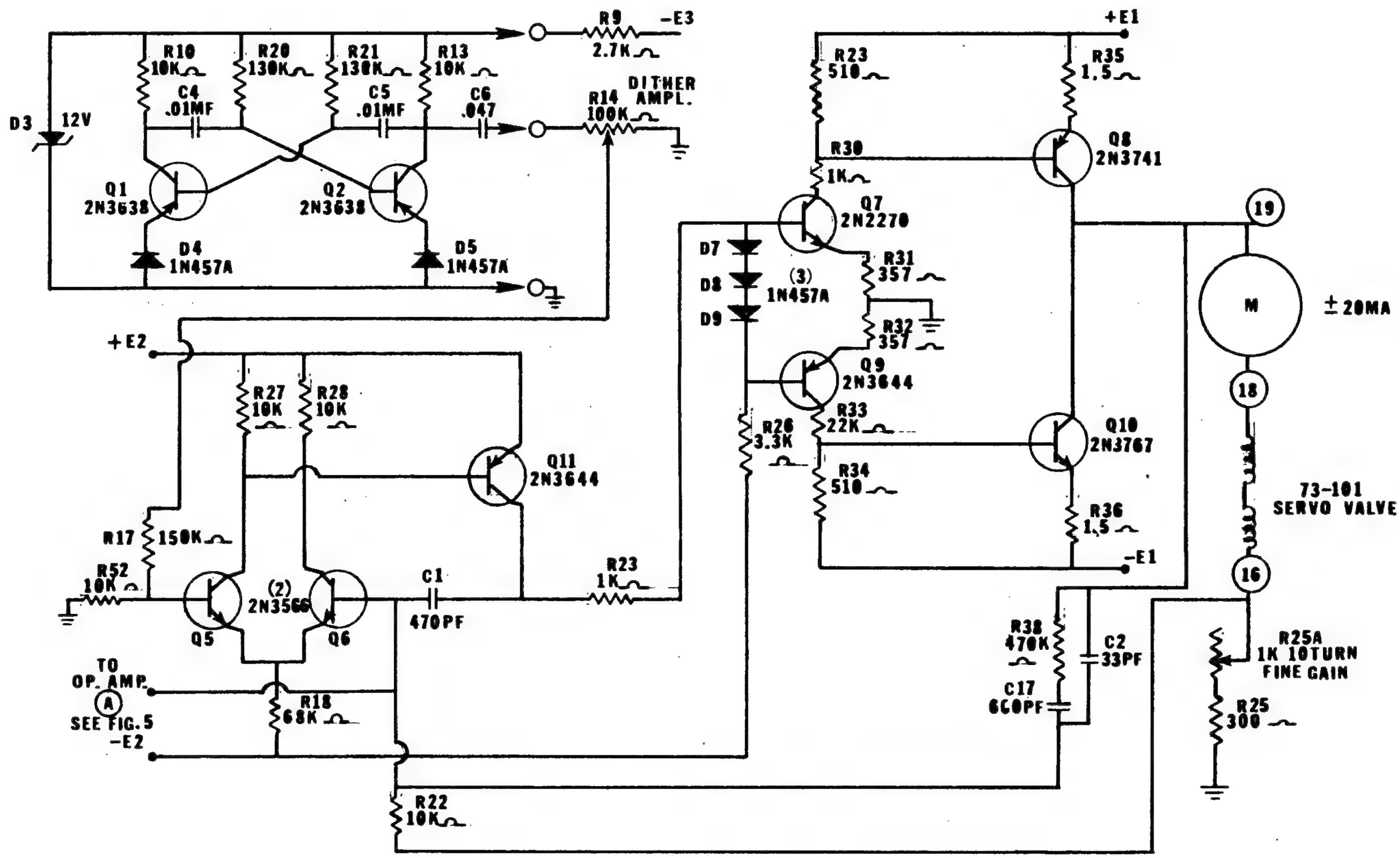


Figure 6 MAIN SERVO AMPLIFIER WITH DITHER CARD

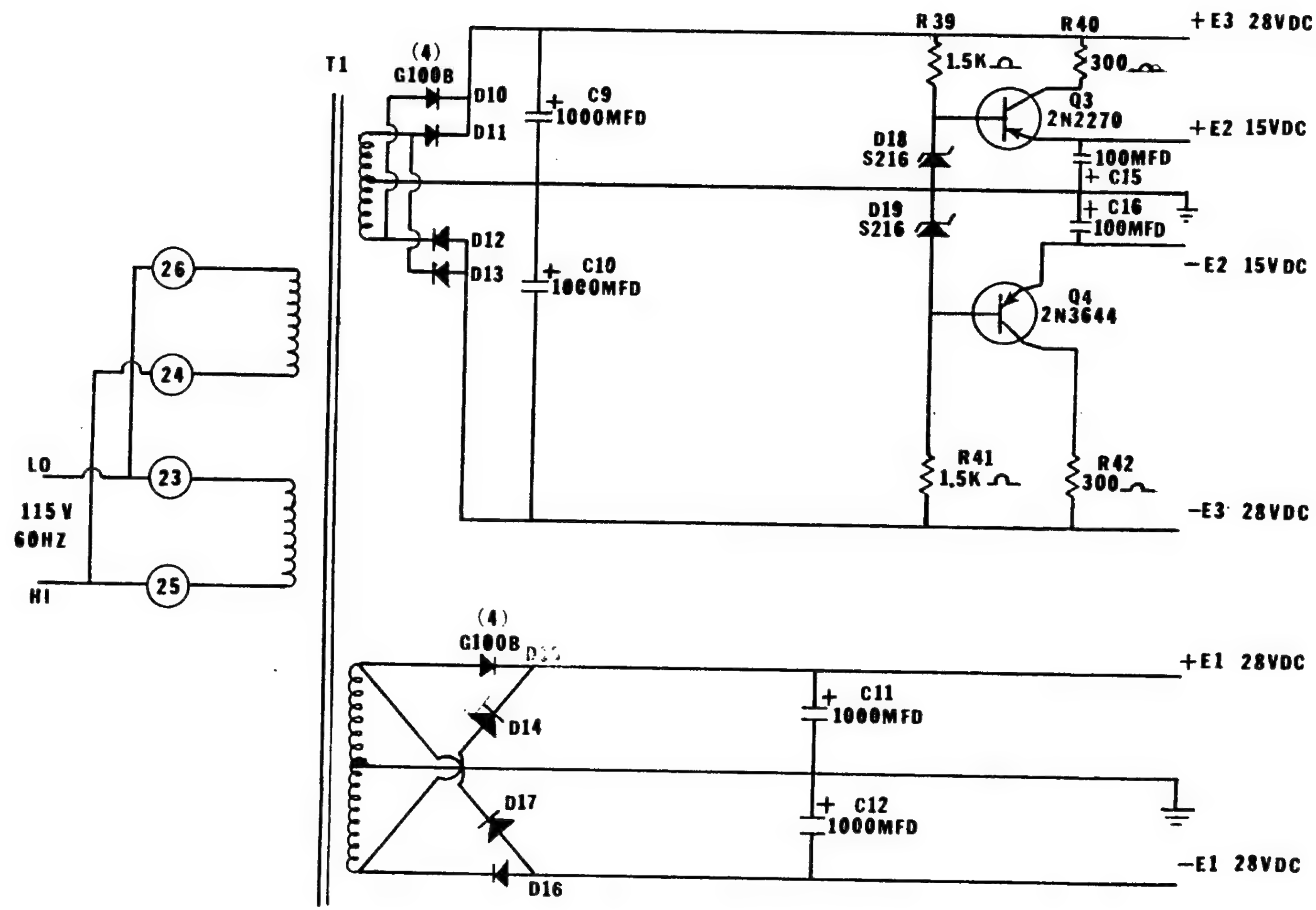


Figure 7 SERVO AMPLIFIER POWER SUPPLY

adjusting potentiometers R6 and R12.) A positive (+) input signal to any input will result in a forward model movement and likewise a negative (-) signal will cause a rearward movement of the model. The servo system operates in a closed loop mode for model positioning. The position set potentiometer is adjusted in such a direction as to provide the model platform location. Clockwise rotation of the potentiometer will produce a forward model movement. The wiper of the position set potentiometer is connected to terminal 10 of the servo amplifier. This terminal routes the position signal through the normally closed contacts of relay K1 to R8A and R8B, a 100K summing resistor. The voltage difference between the position set potentiometer and the feedback signal (error signal from the feedback potentiometer, terminal 2) is amplified by means of the servo amplifier which causes a current to be developed in the servo valve. The valve then opens and directs hydraulic fluid to the model platform actuator. The actuator causes the model platform to move in the desired direction. The feedback potentiometer produces a voltage opposite in sign from that of the signal from the position set potentiometer. When the two voltages are equal in magnitude the output voltage from the amplifier will be zero thus allowing the servo valve to close. It should be noted that there are two position set potentiometers per channel which allow a two position mode of operation for each axial positioning unit. The position set potentiometers can be selected by means of the model programmer or manually for set up purposes. This allows bringing a model into the arc heated flow at the rear most position then moving it to a forward position in the flow. Bringing a model in at the rear most position puts less side forces on the model and is used to keep certain types of models from breaking off as they enter the flow.

The ramp features of this system is used to inject the model from a rearward position to a forward position at a controlled velocity rate. The model axial velocity is preset using the ramp control unit (see appendix D). Each of the 5 independent axial drive units can be set at its own ramp rate. The ramp signal is connected to terminal 7 of the servo amplifier. The ramp signal is added to the signal from the position set potentiometer. The position potentiometer in this case becomes the zero adjustment for ramp control.

Terminal 11 of the servo amplifier is used to accept sensor signals. Relay K1 must be energized in order to provide heat sensor mode of operation. When this relay is energized all position information, including position feedback, is removed from the servo amplifier summing junction and sensor information is then connected. The heat sensor assembly and principles of operation of this unit will be described in detail in Sections VI and VII of this manual.

The main amplifier (see Figure 6) is a conventional solid state amplifier with the exception that a dither oscillator is provided. The dither oscillator is a plug-in board with a frequency of 1 KHz. Note that the dither amplitude is continuously variable by means of potentiometer R14. Potentiometer R25 is used to adjust fine gain for the servo amplifier. The servo amplifier has an output capability of ± 15 milliamperes.

SECTION V

SERVO VALVE

The servo valves used in the RENT axial model positioning system are electrically controlled. The valves and servo amplifiers were purchased from a single source to insure compatibility of these important components. The servo valves are so designed that the hydraulic flow is proportional to the electrical input current. This type of valve allows precise control when used in a closed loop servo system.

The servo valve contains two coils which may be connected in a series or parallel configuration. In the axial model positioning system, series operation of the valve is used. A current of 15 milliamperes will cause the valve to be fully open thus allowing the maximum hydraulic flow rate. It should be noted that due to the differential construction of the valve a positive current will cause forward movement of the axial model platform and a negative current will cause the platform to move in a rearward direction.

SECTION VI

HEAT SENSOR ASSEMBLY

The heat sensor assembly consists of a sensor block for holding the sensors and a junction box for bridge conditioning. Both of these units are mounted under the arc heater nozzle.

The heat sensor block is comprised of infrared detectors mounted in a mechanical housing which also serves as a receptacle for a simple optical system. The mechanical-optical housing is illustrated by means of Figure 8 and a simplified electrical schematic as well as detailed schematics are shown in Figures 10, 11, 12, and 13. The infrared heat sensors are used as the control element for the servo system when testing ablative models. Two sensors are necessary in order to obtain servo control. The heat sensor block is mounted under the arc heater nozzle in the RENT Facility and is adjustable fore and aft to obtain the correct control point with respect to the nozzle.

When under heat sensor control the servo system operates as follows. The model is injected into the flow by means of the lateral carriage mechanism and locked in place by means of a hydraulic pinning mechanism. The model begins to heat as soon as it enters the flow but will not be hot enough for ablation to take place for a period of time dependent upon the model size, shape and material. The model programmer signals the mode controller to switch from position control to heat sensor control just prior to the model being pinned in place. However, the mode controller will not switch from position control to heat sensor control until after the heat sensor comparator sees a sufficient signal on which to control the model. At that time the sensor comparator allows the mode controller to

switch a relay located on the servo amplifier unit to change state, thus switching from position control to heat sensor control. The heated model causes a positive (+) electrical signal to be generated by sensor number 2 which causes the model to drive forward. As soon as the forward moving model comes into the viewing window of the heat sensor number 3 a negative signal (see Figure 9) is produced by this sensor. When the signals from the two sensors are of equal magnitude a state of null is reached and the forward motion is slowed to a rate at which the model material is ablating away. The infrared detectors in use are lead sulphide photo-sensitive resistors connected in a bridge circuit as indicated in Figure 10. There are two detectors for each heat sensor in use. One of the detectors is used as an active bridge arm and the other detector is utilized to provide temperature compensation. Temperature compensation is necessary in order to reduce zero drift which would occur because of changes in ambient temperature.

The remaining part of the bridge circuitry is located in the junction box. It consists of a mercury cell, two resistive arms and a potentiometer to provide an initial bridge balance (see Figures 10, 14, 15 and 16). The mercury cell is used to provide the excitation voltage for each sensor bridge. The type of mercury cell in use is electronically noise free and has a life expectancy of almost two years. The heat sensor block is connected by means of a short cable to the junction box.

The heat sensor block optics must be adjusted so that the model will be controlled at the proper distance from the nozzle. An electrical calibration of the relative sensor sensitivity must be performed from time to time as a check on sensor performance.

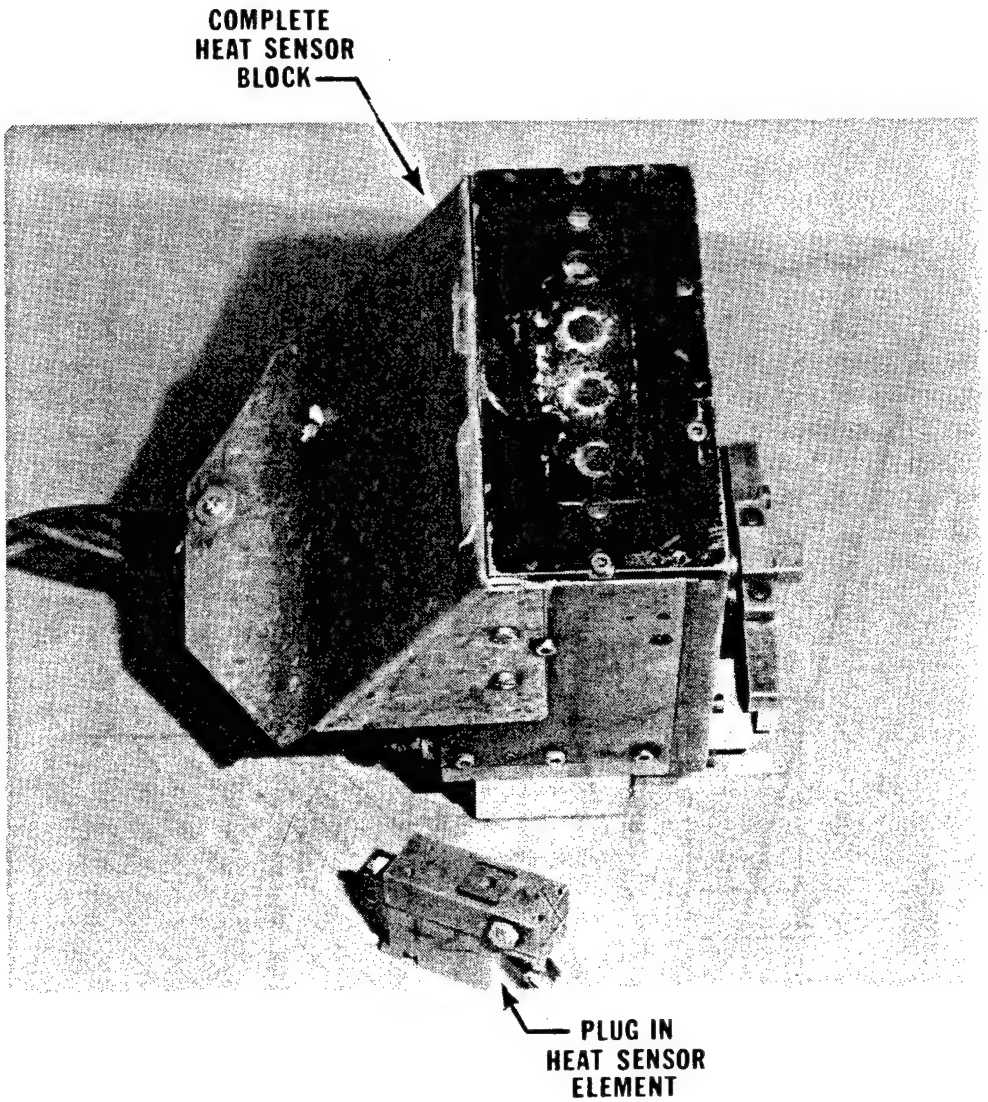


Figure 8 HEAT SENSOR BLOCK

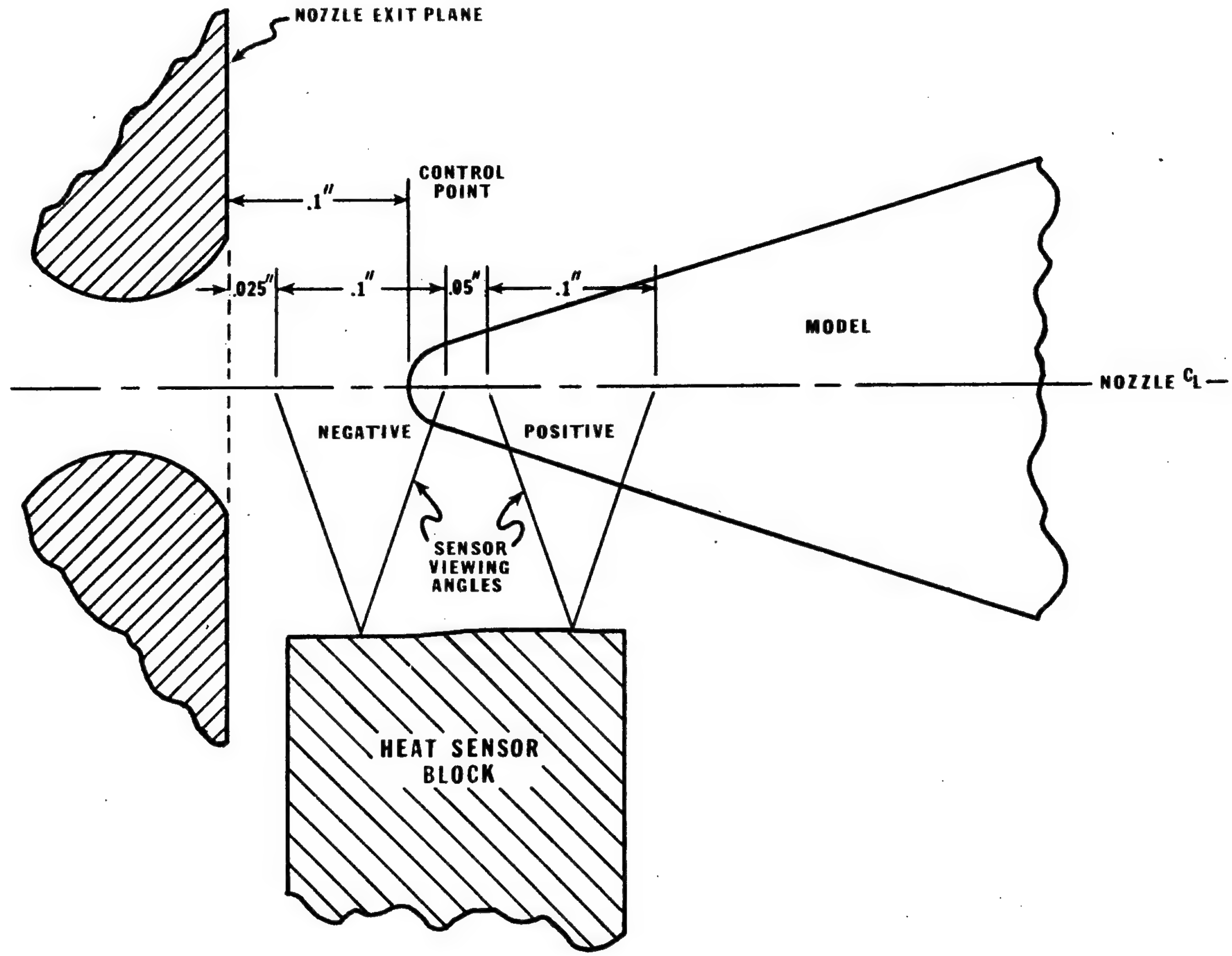


Figure 9 HEAT SENSOR VIEWING ARRANGEMENT

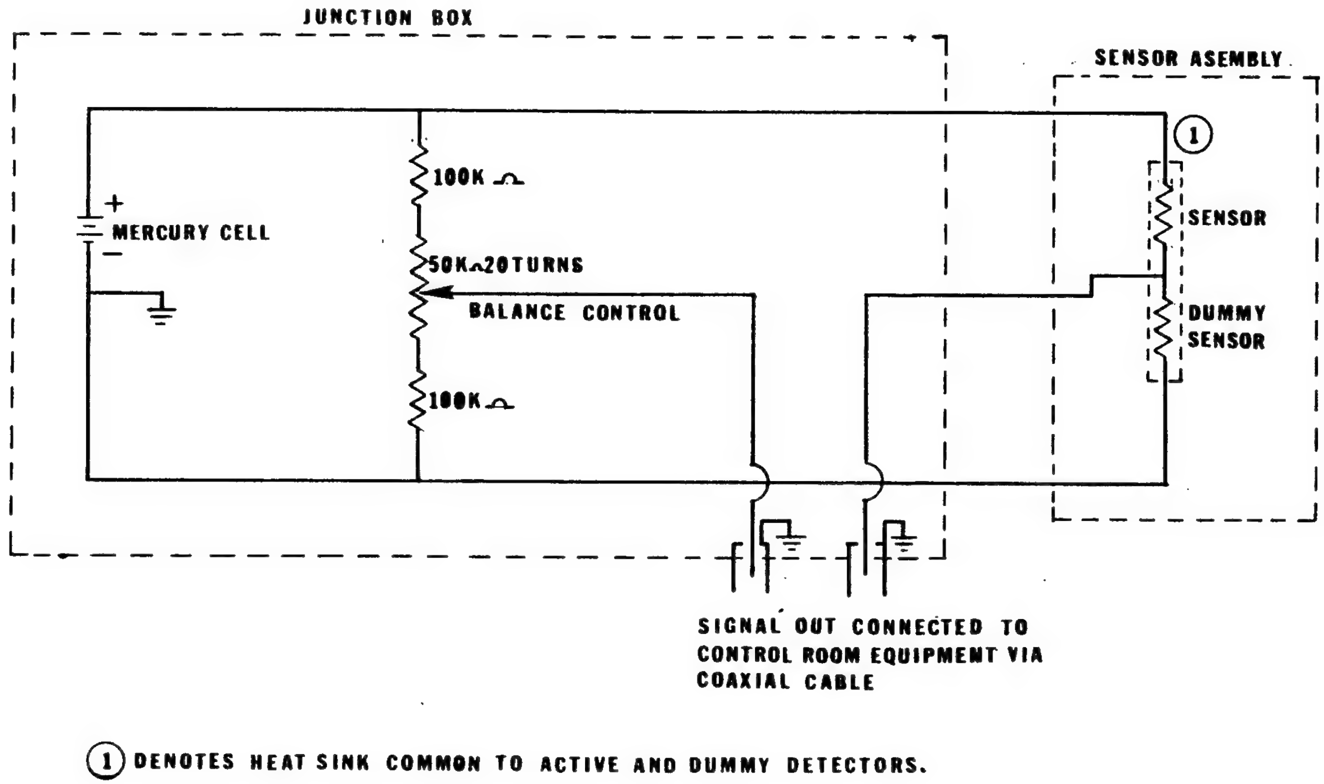


Figure 10 HEAT SENSOR SCHEMATIC SIMPLIFIED

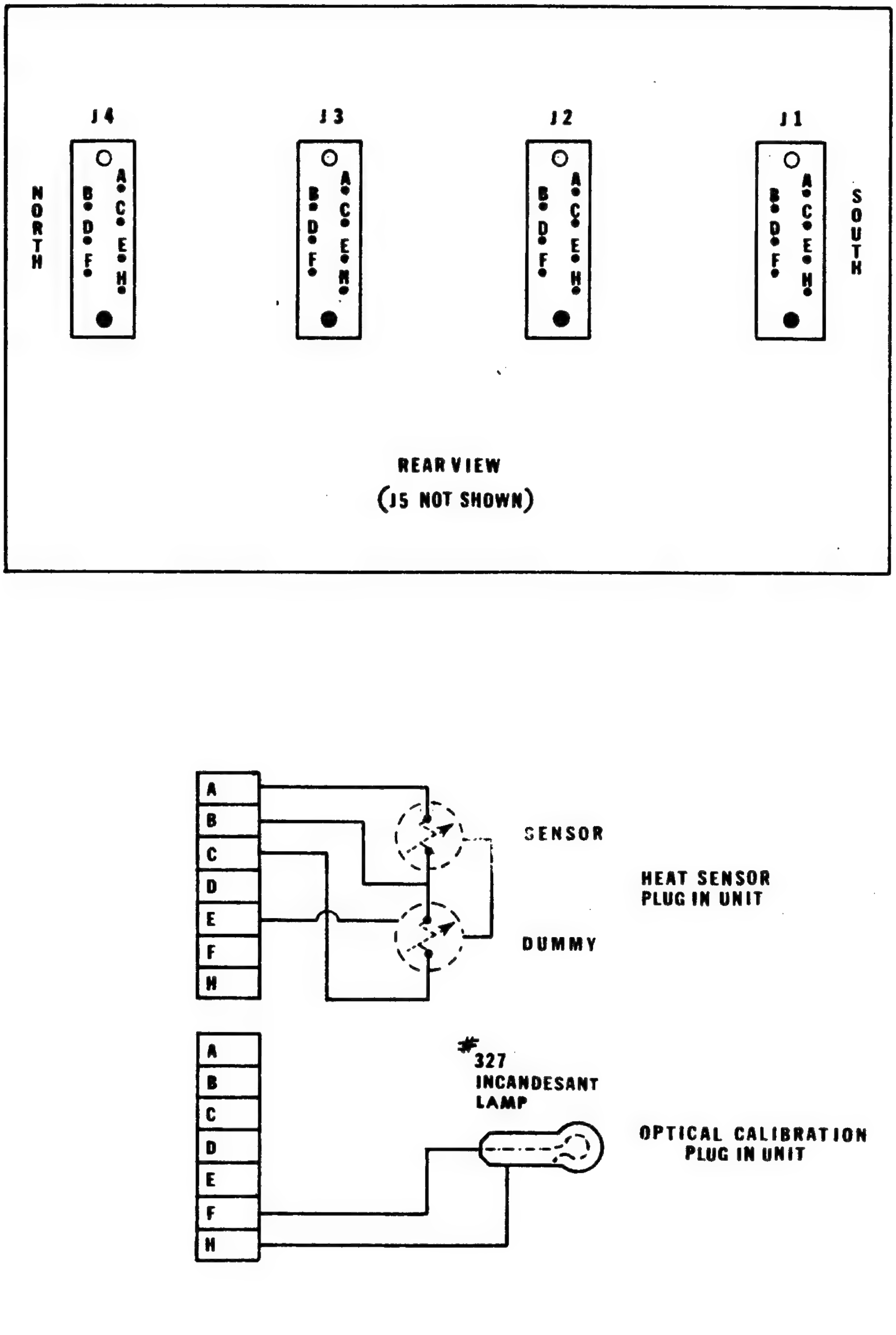


Figure 11 HEAT SENSOR BLOCK PLUG-IN WIRING DIAGRAM

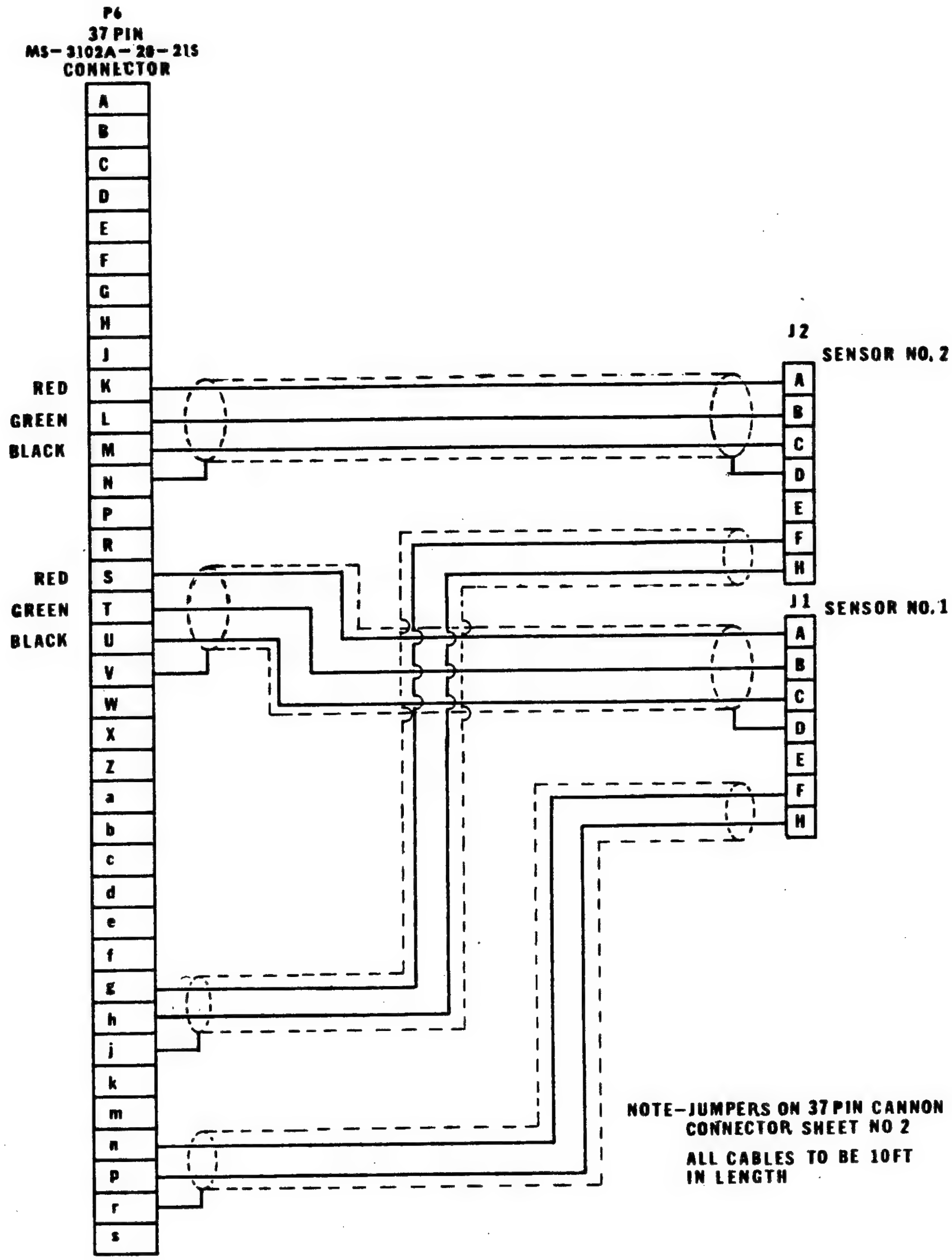


Figure 12 HEAT SENSOR BLOCK WIRING DIAGRAM (SHEET 1 of 2)

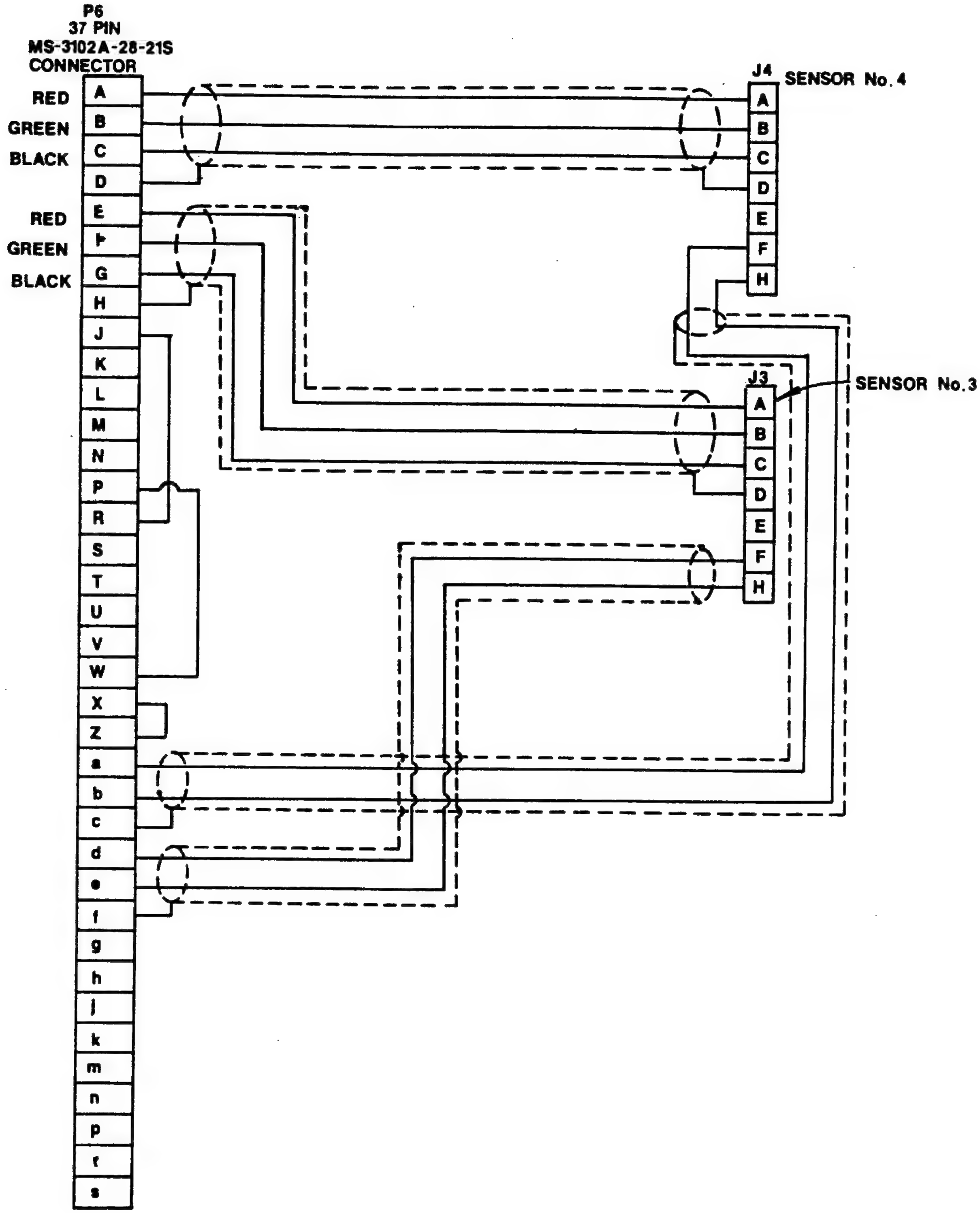


Figure 13: HEAT SENSOR BLOCK WIRING DIAGRAM
SHEET 2 of 2

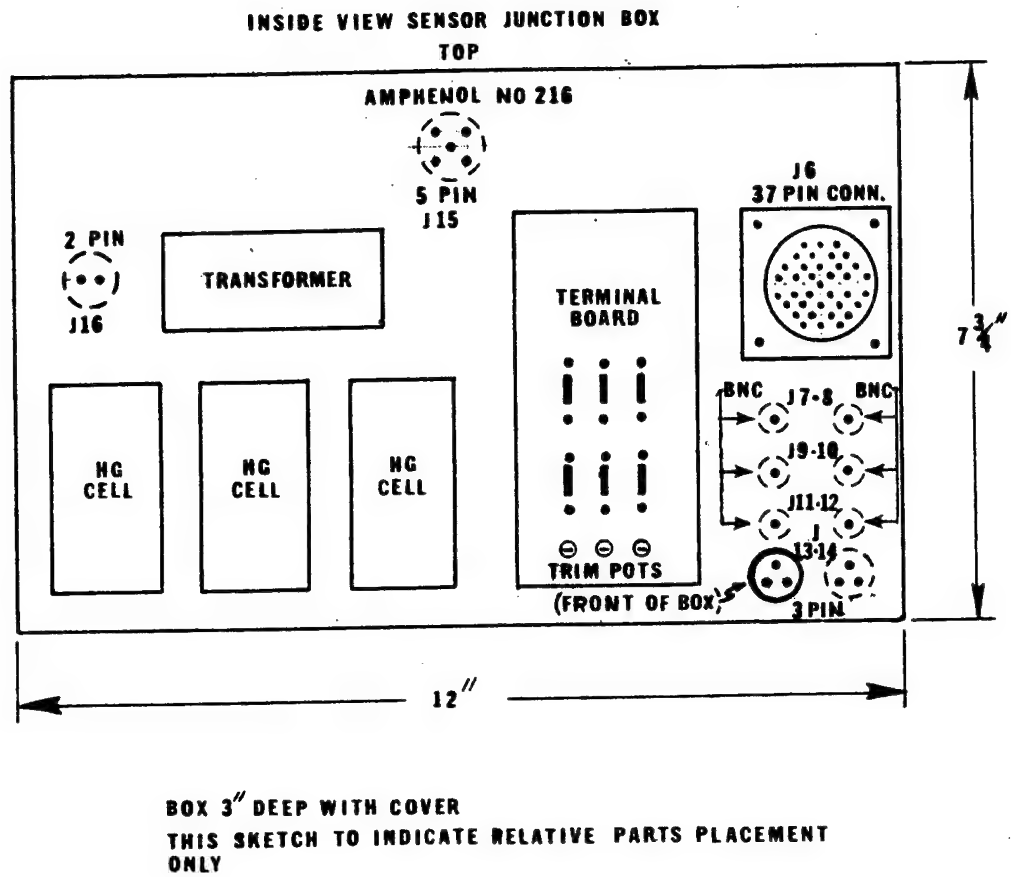


Figure 14 SENSOR JUNCTION BOX PARTS PLACEMENT

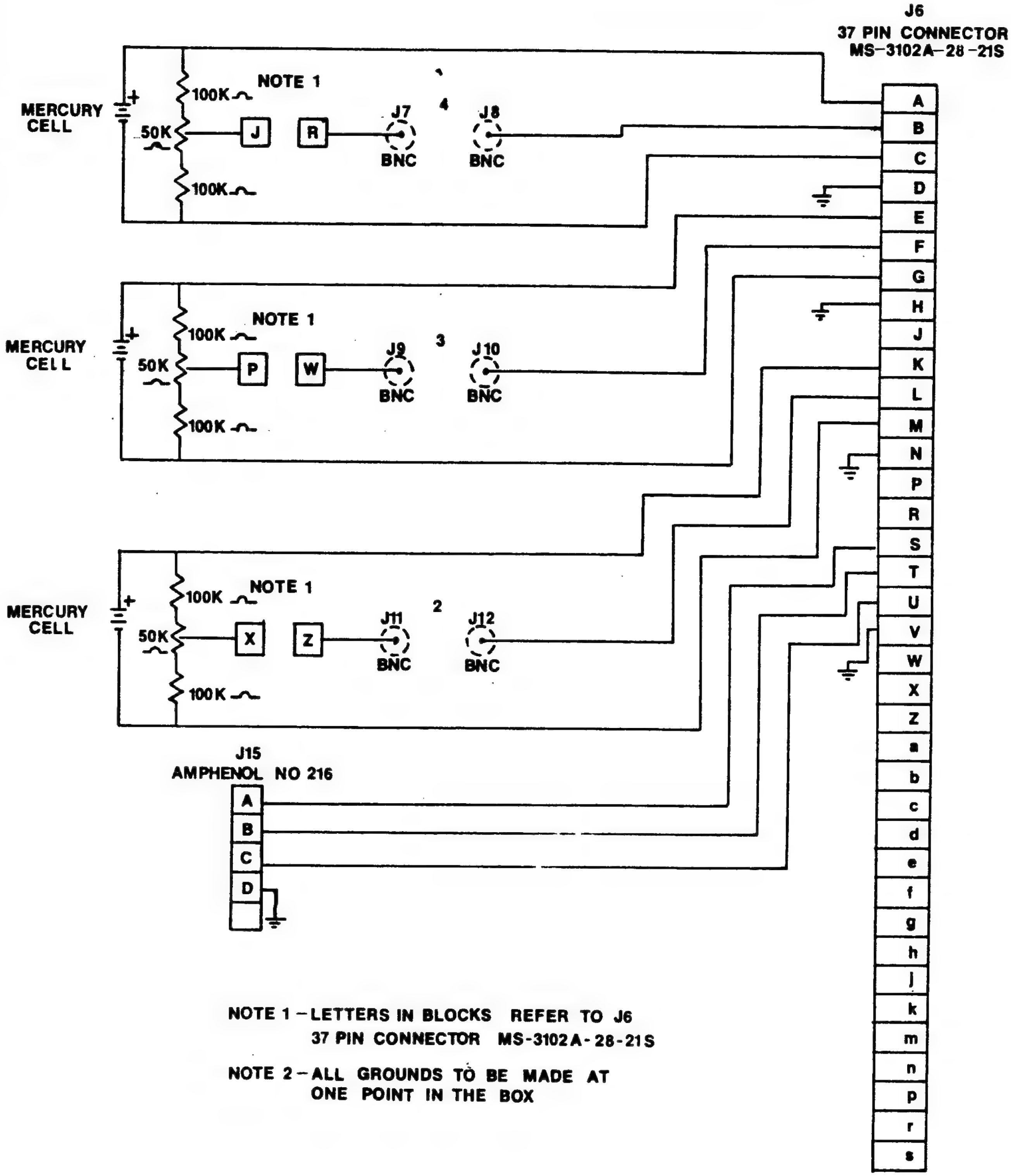


Figure 15 SENSOR JUNCTION BOX (Sensor Wiring) (SHEET 1 of 2)

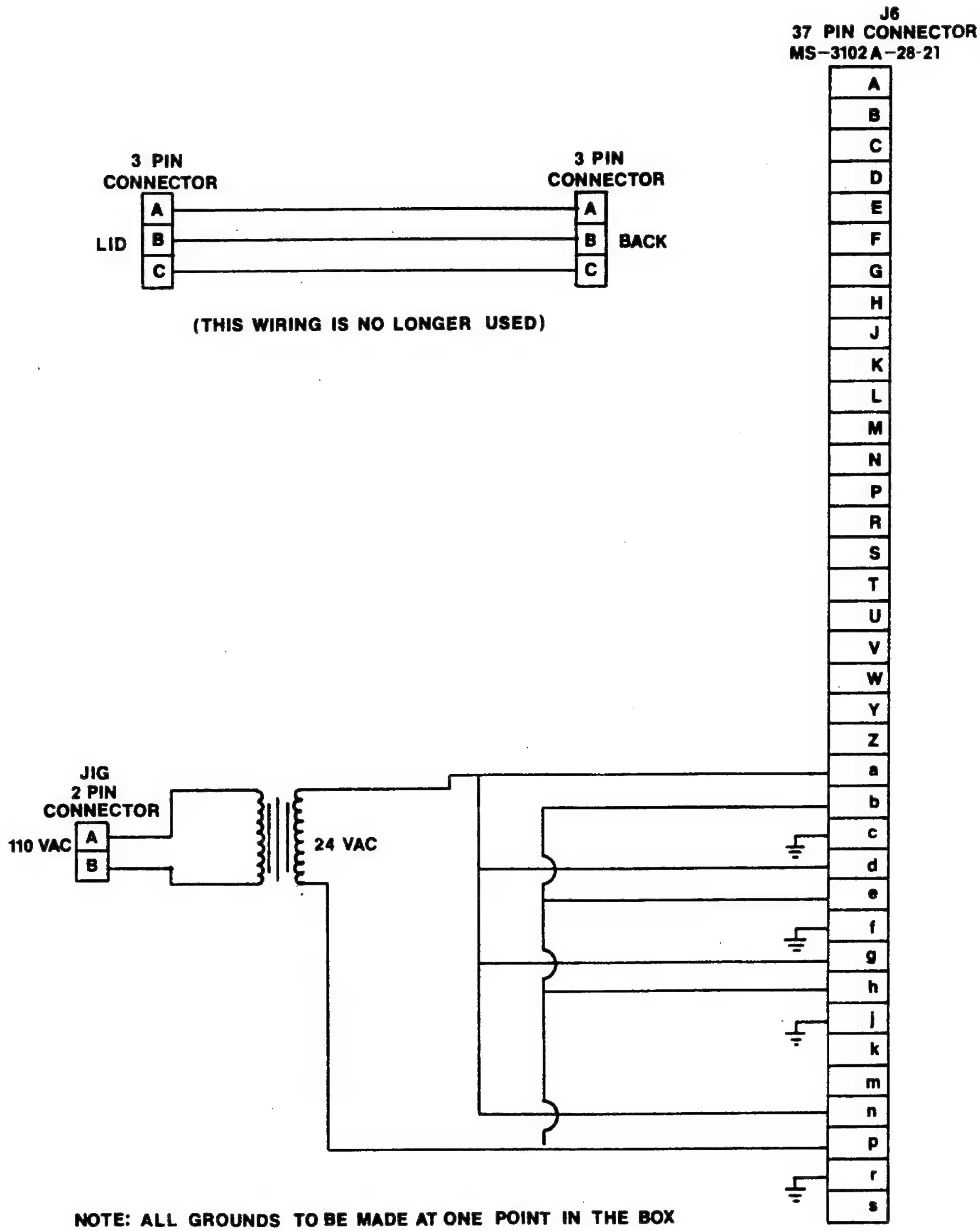


Figure 16 SENSOR JUNCTION BOX (Power Wiring) (SHEET 2 of 2)

Four plug-in units identical to the heat sensor plug-in units were fabricated, but in place of the infrared detectors, 28 volt miniature lamps were installed. A 24-volt transformer installed in the heat sensor junction box is used to provide power for these lamps. When alignment of the heat sensor optical system is necessary the sensor plug-in units are removed. The plug-ins containing the lamps are inserted and power is applied to the lamps. In a darkened room the light from the lamps projects through the optics in a reverse path. The optics can now be adjusted for maximum performance and proper optical point with respect to the nozzle. When the optical alignment is completed the detector plug-in units should be reinstalled in the heat sensor assembly.

A test fixture was fabricated in order to perform a calibration check of the heat sensors and the related signal conditioning equipment. The device is essentially a flat plate on which are mounted four moveable holders containing 28-volt lamps. The fixture when in use is mounted on top of the heat sensor assembly and 28-volt DC power is applied to the lamps. A digital voltmeter connected to the sensor amplifiers is then used to read the value of voltage produced by each sensor. The adjustments provided on the test fixture make it possible to center the lamps with respect to the detectors thus maximizing the output that may be obtained from the detectors. When the initial calibration is performed the voltage value for each sensor is entered in a log. Each time the device is used the sensor outputs are compared to the original value thus establishing a normal output voltage for each sensor. If the heat sensor voltage becomes lower than the normal value the discrepancy should be resolved before the facility is operated.

SECTION VII

HEAT SENSOR SIGNAL CONDITIONING SYSTEM

The heat sensor signal conditioning system is comprised of three operational amplifiers connected as shown in the block diagram of Figure 17. Figure 18 contains the complete schematic for buffer amplifiers number one and two. The third amplifier (see Figure 19) sums the outputs of the buffer amplifiers. The third amplifier is electrically the same as the buffer amplifiers with the exception of the gain setting resistors. The wiring between the amplifiers is shown in the case wiring diagram, Figure 20. All three amplifiers are instrumentation type amplifiers. The amplifier was selected to provide low temperature drift, high input impedance and good common mode rejection. The amplifier was also selected to allow linear gain adjustment. The gain of the third amplifier may be read out directly by means of a ten-turn potentiometer and associated dial assembly.

The heat sensor bridge signals are connected to the amplifier input terminals by means of RG-59U coaxial cables. Coaxial cable is used to insure satisfactory frequency response, low phase shift, and a good signal to noise ratio.

Two coaxial cables per sensor are used. One of the coaxial cables is necessary in order to insure proper frequency response etc. as noted above. The other coaxial cable is necessary because two cables of like construction will "pick up" approximately the same amount of electrical noise, and this noise will be eliminated in the differential input circuit of the buffer amplifier.

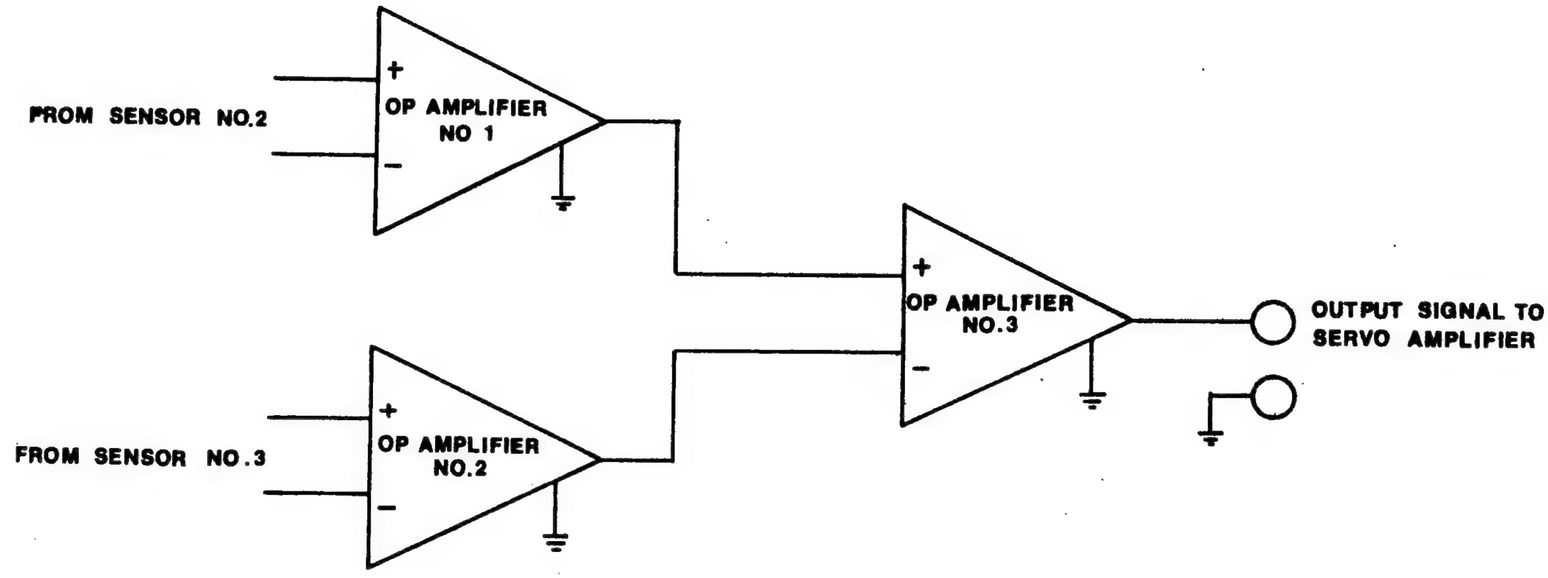


Figure 17: BLOCK DIAGRAM OF THE SENSOR AMPLIFIERS

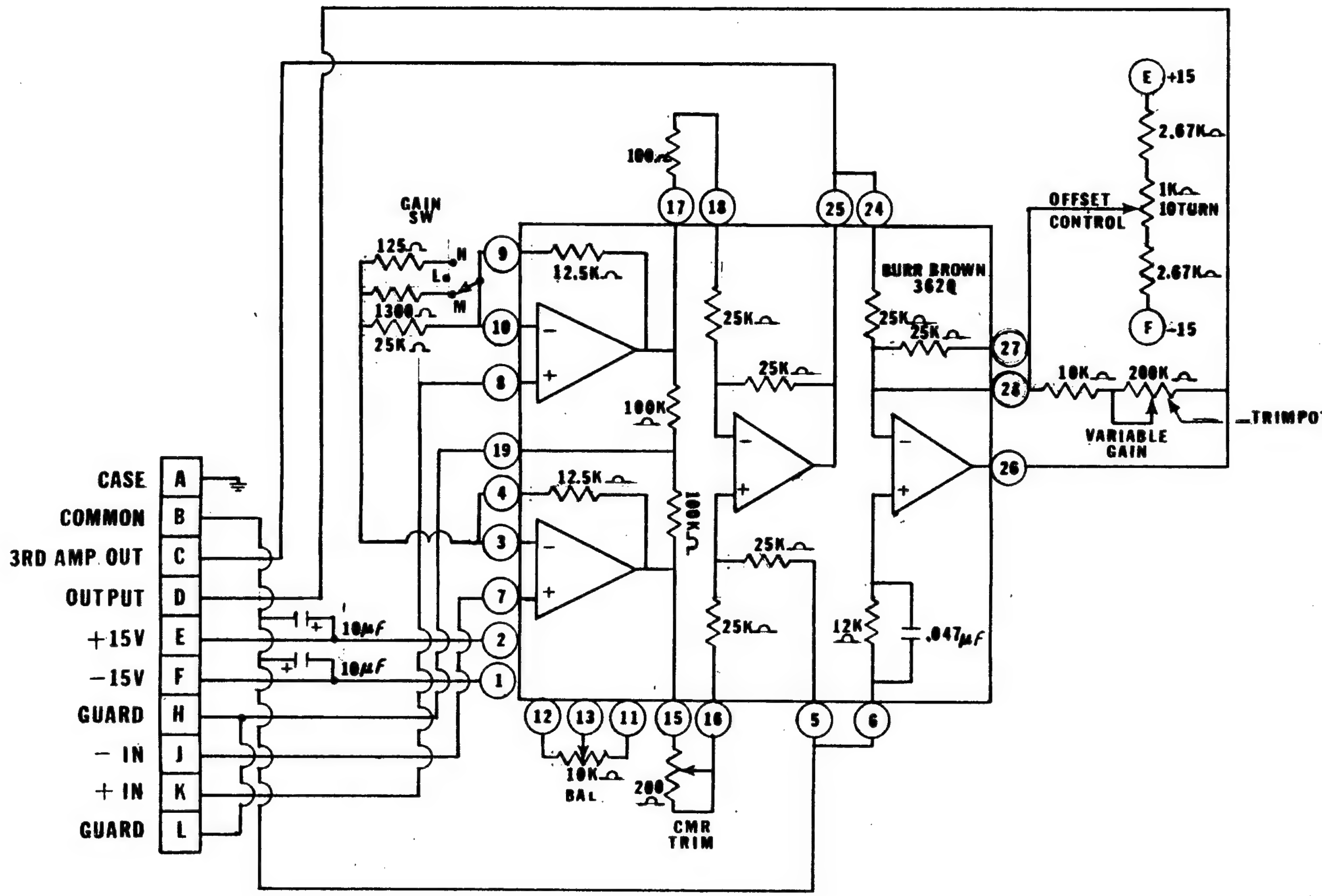


Figure 18 BUFFER AMPLIFIERS NO. 1 and 2 SCHEMATIC DIAGRAM

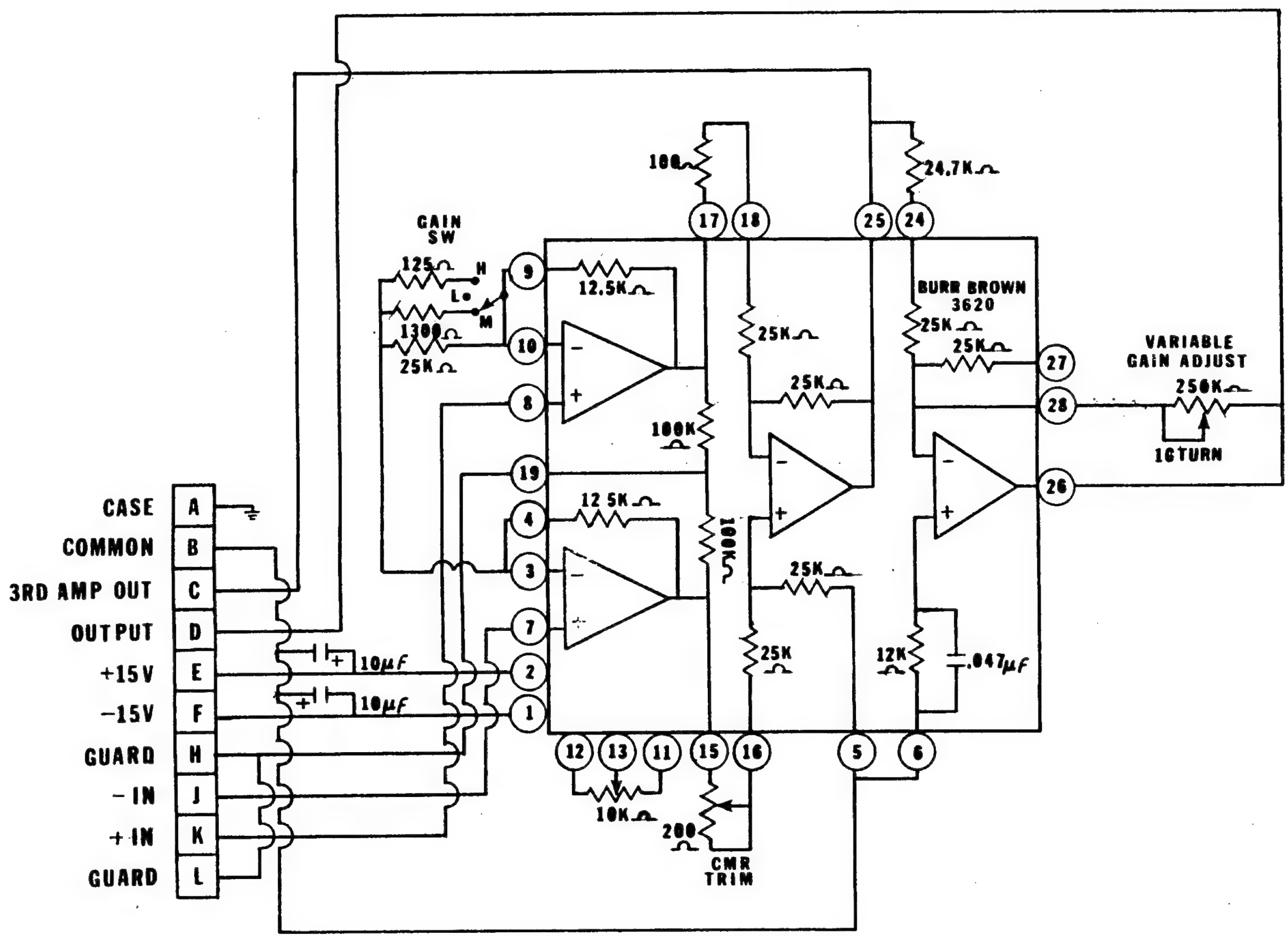


Figure 19 AMPLIFIER NO. 3 SCHEMATIC DIAGRAM

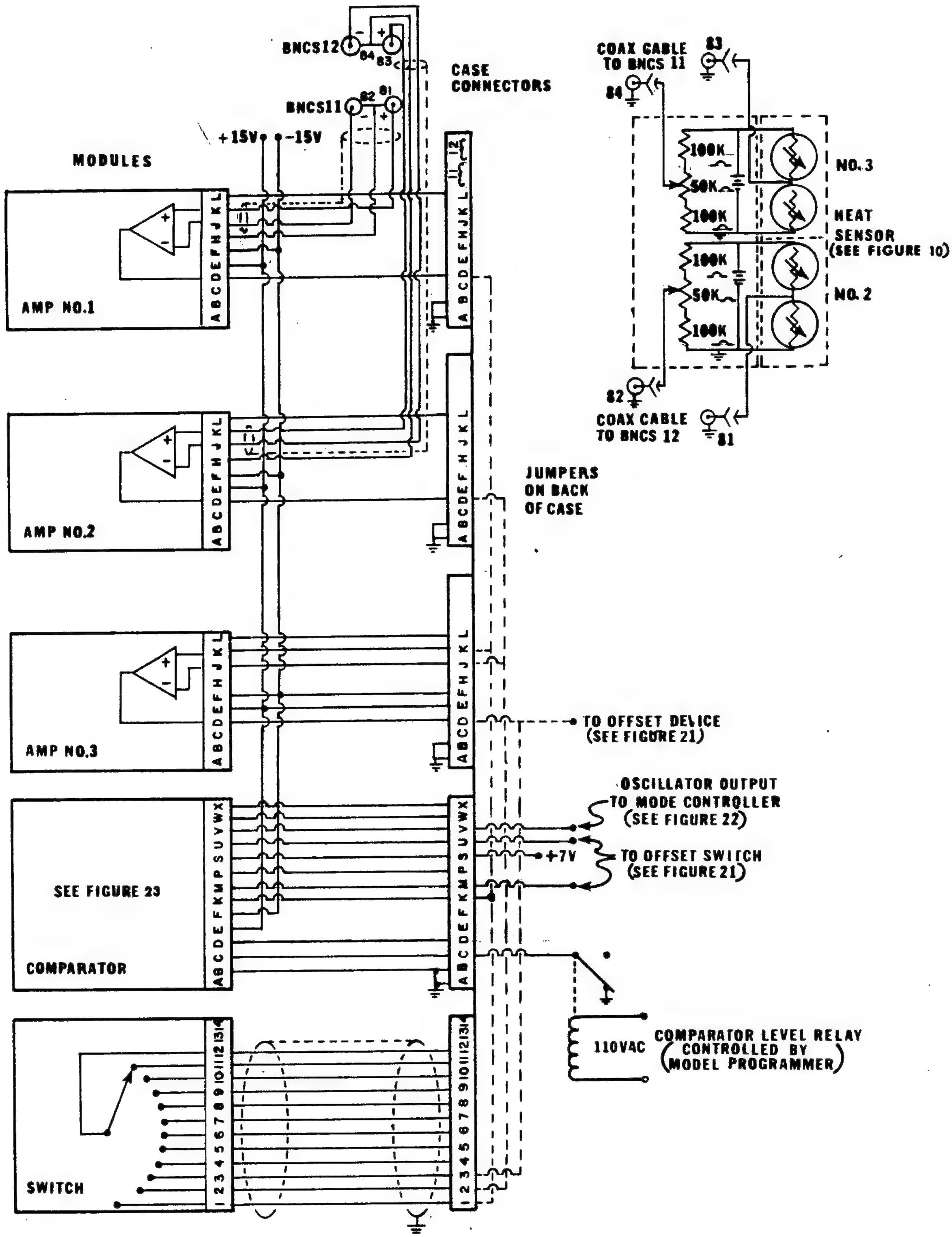


Figure 20 MODULE TO CASE WIRING

The heat sensor bridge circuitry is identical in every respect for both the positive and negative sensors. The signals from the sensors are therefore identical with respect to voltage polarity. A voltage of positive polarity is maintained through the buffer amplifiers. The signal from the "negative" sensor is inverted by the summing amplifier (amplifier number three) and therefore a negative signal is produced.

The output terminal of the third amplifier is connected to the heat sensor input of the servo amplifiers through an offset device (see Figure 21). The offset device adds a positive (+) bias voltage to whatever signal is present at the output terminal of the third amplifier. The bias voltage is necessary to insure that the model moves forward over the viewing area of the heat sensor optical system. The offset voltage is variable from zero to five hundred millivolts. The offset can also be reversed to drive models away from the nozzle on cold blows (checkout runs made without starting the arc heater).

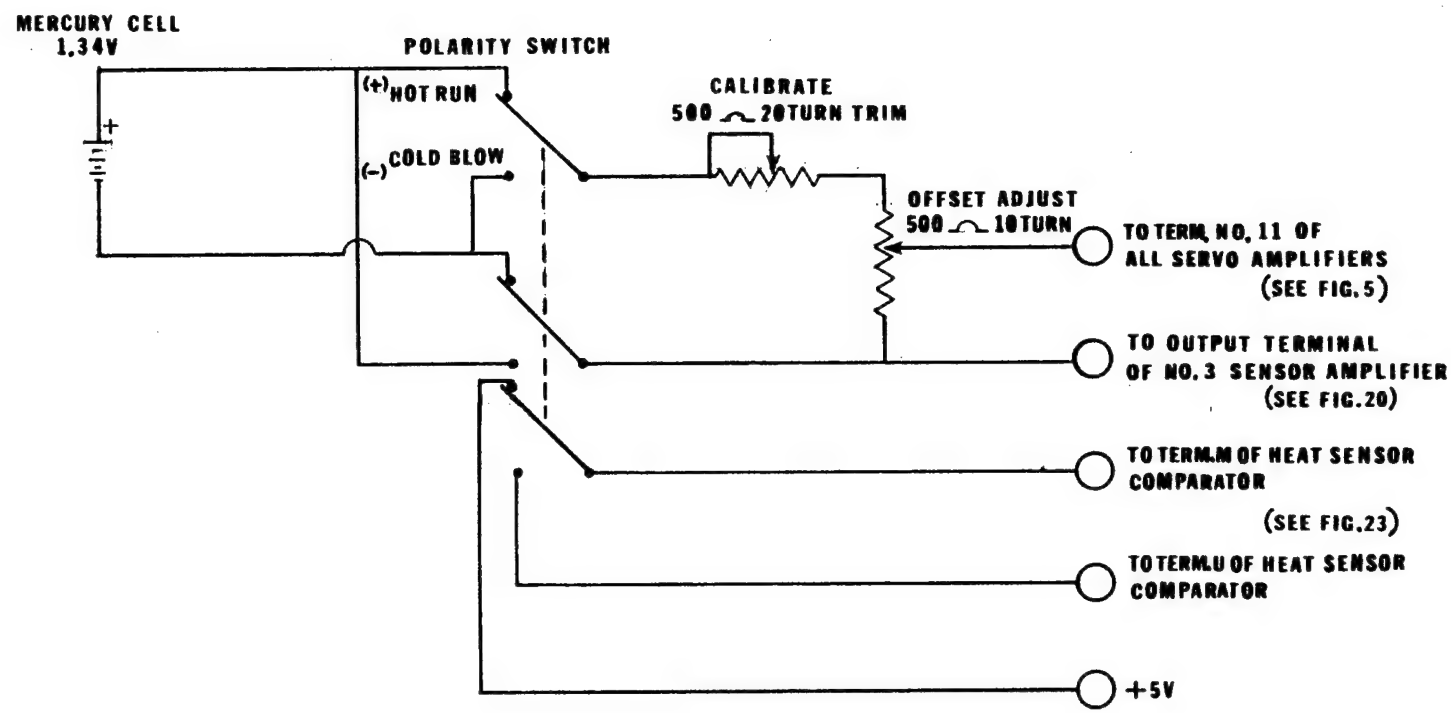


Figure 21 OFFSET DEVICE SCHEMATIC

SECTION VIII

MODEL PROGRAMMER AND MODE CONTROL

The RENT Facility Model Programming System was installed to control all model operations including both the lateral carriage movement and axial position control. The programmer is an all electronic, solid state device designed to provide thirty-six timed steps or events and a like number of electronic switches. The programmer is actually made up of 3, 12 step solid state controllers operating sequentially. The time for each event may be adjusted over a range of from .01 seconds to 10,000 seconds. Any event may trigger from one to twelve electronic switches. The programmer will switch alternating current (AC) only. Therefore any DC loads must be buffered by means of suitable AC relays. As an example, a double pole double throw AC relay is actuated by the application of 120-volt 60-Hz power by means of the model programmer. The contacts of the relay switch 5 volts of DC power to the start and reset terminals of the mode controller. In addition to controlling laterial and axial model positioning equipment the programmer is used to start and stop cameras, oscillographs and any other device which must operate on timed basis. It should be noted that the model programmer will not switch current into large inductive loads unless a resistor of approximately 2K ohms is connected in parallel with the load.

The model programmer as stated before drives the five individual mode controllers via AC relays. The mode controllers (see Figure 22) are designed to switch the axial model positioning system from the position control mode to the heat sensor mode. The mode controllers work in conjunction with the heat sensor comparator (see Figure 23). Upon activation by the programmer of the relay for driving a mode controller, the five

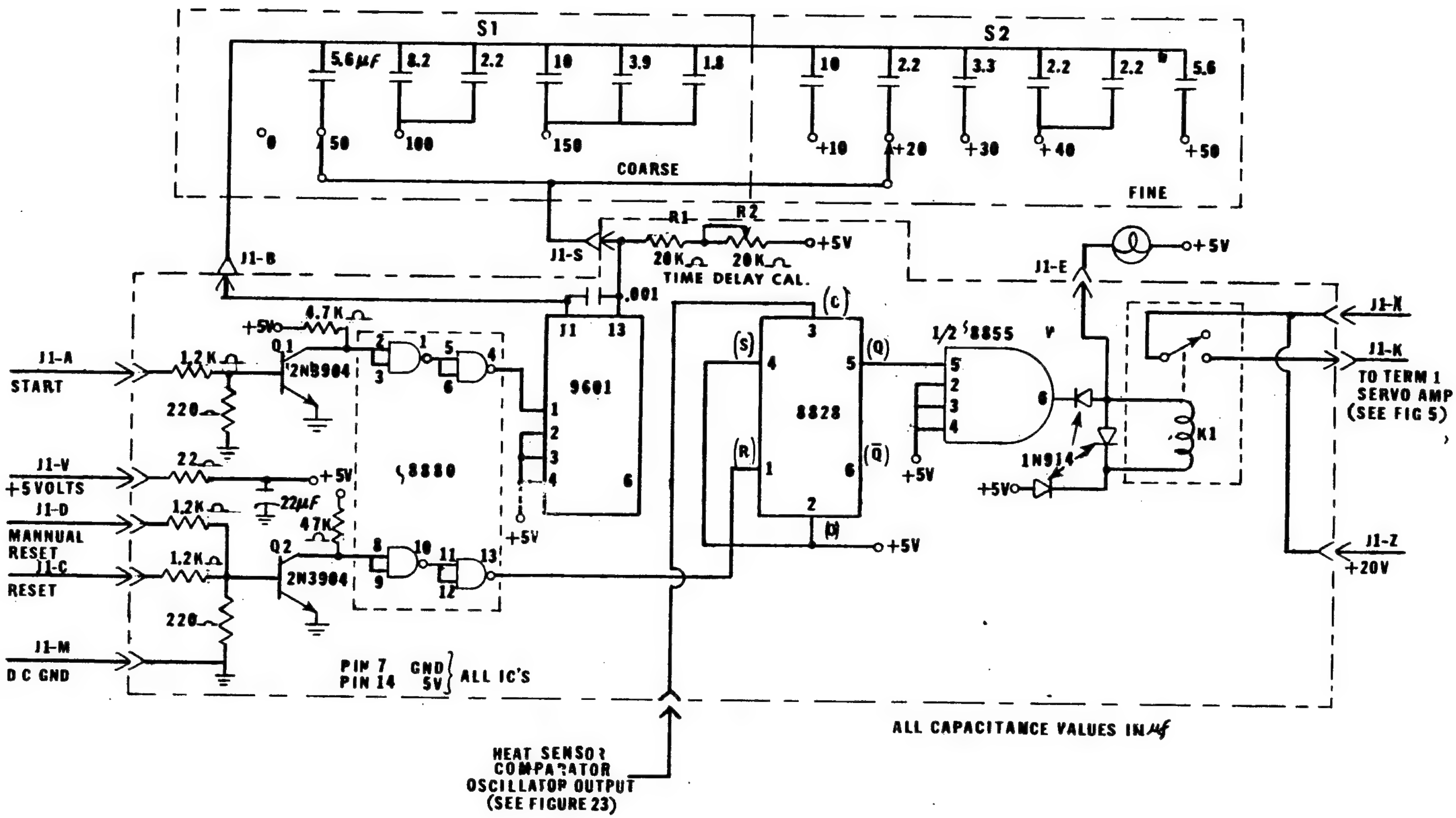
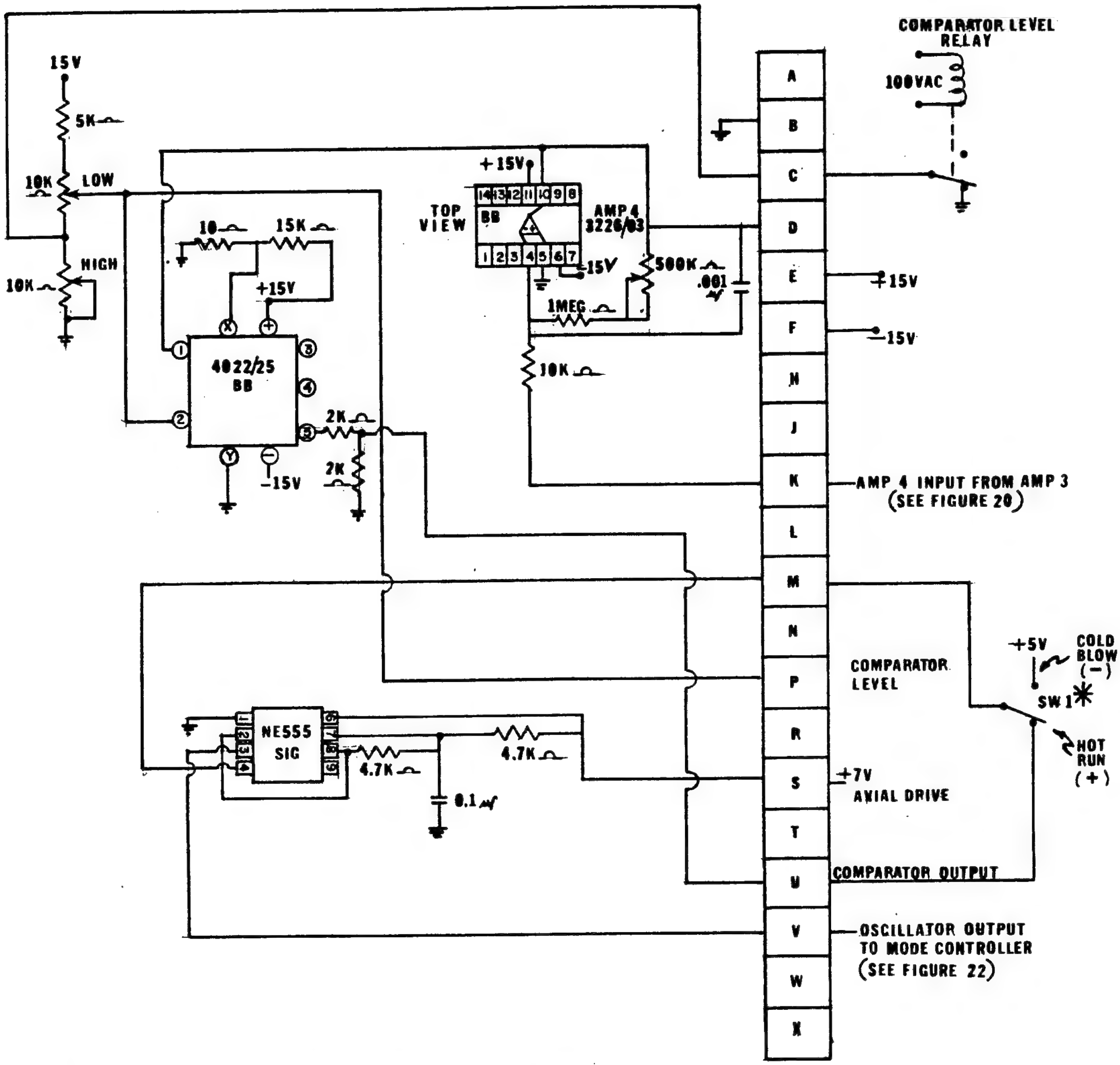


Figure 22 MODE CONTROLLER

volt level on the reset line J1-c is removed and it is grounded. This removes the reset from flip-flops (8828) and allows it to change logic states upon receiving a clock pulse from the heat sensor comparator oscillator output. The flip-flop changing states enables the relay drive (8855) to energize the relay K1. Energizing relay K1 connects 20 volts DC to terminal number 1 of the servo amplifier (see Figure 5) thus activating relay K1 of the servo amplifier. This connects the servo amplifier to the heat sensor signal. When the model programmer removes power from the mode controller driver relay, the five volt level is again applied to the mode controller reset line (J1-c). This in turn resets the flip-flop and deenergizes the relays returning the servo amplifier to position control. By maintaining the five volt logic level on the reset line, good noise immunity is provided. The time delay circuitry using the start line (J1-A) and one-shot multivibrator (9601) is no longer used to activate the flip-flop (8828) due to the difficulty in estimating the time required for individual models to reach a high enough temperature to allow heat sensor control.

The heat sensor comparator (see Figure 23) is now used to determine when the model provides sufficient heat radiation to allow controlling it with the infrared heat sensors. Amplifier 4 (3226/03) amplifies the heat sensor signal from amplifier 1. This signal is feed to the voltage level comparator (4022/25). The comparator compares the heat sensor signal with an adjustable trigger level to trigger the oscillator (NE555) on when the heat sensor signal is above the set level. Two different trigger levels can be used during any one run by having the model programmer activate the comparator level relay for the level wanted. With the relay deactivated the comparator is in the low level mode. When activated the

comparator is in the high level mode. For checkout runs (cold blows) the offset polarity switch which is set to the negative (-) position supplies a 5 volt trigger level to the oscillator keeping it on for the entire time.



* SW 1 OFFSET POLARITY SWITCH SHOWN IN HOT RUN POSITION. IN COLD BLOW POSITION PROVIDES TRIGGER FOR HEAT SENSOR CONTROL. (SEE FIGURE 21)

Figure 23 HEAT SENSOR COMPARATOR

SECTION IX

SAFETY SYSTEM

The safety system for the model axial positioning system was designed as a complete system which when installed would fulfill the necessary safety requirements for both the lateral and axial model positioning system. Since the safety system was designed and installed to provide the dual functions of providing for both the lateral and axial safety requirements no attempt was made in this memorandum to breakout the portions of the system which deal only with the axial system.

The following paragraphs serve to inform the reader of the need for a safety system and the manner in which the system evolved. The maintenance chapter (see Appendix C) of the memorandum contains the necessary information of use in troubleshooting the safety system.

A. Following the addition of the axial drive capabilities to the Re-Entry Nose Tip Test Facility (RENT) model control system, the following safety requirements were deemed a necessary part of the total system:

1. In the event of a facility failure which results in shutdown of the arc-heater, the lateral motion of the model carriage should be immediately stopped and the individual model struts should be moved to the rearward most position of their axial travel.

2. In the event of a model maneuvering system failure which involves all five model struts an emergency facility shutdown should be initiated. From this point the same actions described in requirements A1 should occur.

3. In the event of a model maneuvering system failure which involves only certain individual model struts, those model struts affected should be made to move to the rearward most axial position and the remainder of the model carriage maneuvering program should continue as planned.

4. The system should have as part of its capability the option of removing any model strut from the arc-jet flow field at any time prior to its programmed removal without affecting the remainder of the maneuvering program. Control of this motion should be by the responsible test engineer directly.

B. Requirements A1, A3 and A4 have been met in their entirety and A2 has been accomplished except in the event of failure of one component in the system. The means of accomplishing the above goals are explained below.

1. The key to establishing a safety system to meet the requirement of paragraph A1 is distinguishing those times when both the model carriage and the arc-heater are being operated simultaneously. During these times the safety system should be active and at all other times should be deactivated. The system must be inactive at times when the carriage is not being operated to prevent the occurence of unnecessary safetying actions during start-up of the arc-heater. It is not uncommon during a start-up that the arc-heater will fire and run for several seconds and then stop, causing a facility failure indication. If the safety system is active at this time it will be triggered needlessly. However, if the system is not activated until both the arc-heater and the carriage are operating, these false indications are ignored and only those failures which could conceivably damage the test models can trigger the safety system.

Thus the safety system for requirement A1, normally referred to as the facility abort safety system, is activated by two events. The first event is the energizing of a relay in the air start controller for the arc-heater. This relay is activated by the initiation of the arc current. The second event is the energizing of a relay which is controlled by the first step in the model programmer used to control the motion of the model carriage. With the energizing of the second relay, motion of the carriage has either begun or is about to begin. After the occurence of these two events the safety system is active and cannot be de-energized except by the opening of a set of switch contacts located at the end of the model carriage track. The model carriage trips this switch at the end of the lateral sweep motion indicating that the test sweep is complete and protection of the models is no longer necessary. At an instant between the arming and disarming of the system, however, a drop in the arc-heater current to zero will trigger the safety system. The triggering signal is obtained from the same relay contacts in the air start controller as are used for the arming signal.

In the event that the arc-heater current does go to zero during this period the following actions occur: (1) Two relays are energized which close both locking valves on the model carriage main hydraulic cylinder. This locks the carriage at whatever position it may be in at that time. (2) A relay in each of the signal leads to the five axial drive hydraulic servo valves is operated disconnecting each valve from its respective servo amplifier and applying a negative signal to the valves causing each strut to move to the rear axial drive position. Once these events occur, the system can only be returned to normal by first turning off the power to the safety system and then switching off the carriage system main electrical power. The occurence of a facility safety abort is also indicated by a panel light on the master control unit.

2. There are four components of the model control system which could concievably affect the operation of all five model struts. These components are the 60 Hz power source for the system, the power supply for the feedback potentiometers on the five model struts, the power supply for the integrated circuit components in the heat sensor control equipment, and the negative reference supply for the heat sensor operational amplifiers. Failure of the first component will result in failure of the entire system regardless of what mode of operation of the model maneuvering system is being used. Loss of the second component will result in system failure in any instance where position control of one or more of the models is being exercised. Failure of the last two components will only result in system failure if an attempt is made to place a test model under heat sensor control.

Since all of these four critical components are power supplies of some sort they are easily monitored with commercial type relays. Each supply has connected across its power terminals an appropriately sized relay such that if the supply fails the relay contacts open. The five relays are all connected to an annunciator trip control for one of the annunciators on the facility power console. Opening of any one of the relays results in an automatic shutdown of the arc-heater and therefore triggers the facility abort system described earlier.

It was realized during the installation of this system that there are certain weaknesses inherent in these protective methods. There is the possibility involving either the IC supply or the feedback potentiometer supply that a partial drop in the supply voltage could cause system failure without activating the safety system. To avoid this occurrence the relays used to monitor these particular units were chosen such that they will release at a voltage level higher than the

level which was arbitrarily decided to be the minimum allowable for operation of the associated system. Also the above protection procedures do not guard against over voltage type failures. Although such failures would downgrade the performance of the system, they normally should not prevent the system from operating and an emergency shutdown should not be necessary. Both of these limitations could be avoided by using bi-level voltage comparators, but it was decided, considering the improbability of these types of failures, that the extra expense and complications required to install such protection were not justifiable. Of course it should also be realized that there are electronic components within the carriage control system whose failure would disable the entire system and which cannot be monitored continuously. The protective equipment that is installed is aimed at guarding against what are considered to be the most probable trouble areas and is not offered as 100% protection against failures which fall under the second safety requirement.

As was noted earlier there is one component of the axial drive system which is a probable trouble area and which has not been included in the protective coverage of the installed safety systems. That component is the axial drive heat sensor unit. The heat sensors do not lend themselves to protective monitoring simply because of the wide range of valid impedance levels which they may exhibit and because it is not known what the typical characteristics of a sensor failure are. The addition of the heat sensor comparator, however, has provided some protection from a heat sensor failure. If an adequate signal is not present from the heat sensor the model will remain at a fixed axial position. This will be true for normal ablation testing only and will not protect against models being ramped forward and switched to heat sensor control.

3. The techniques used to meet safety requirement A3 are similar to those used in meeting the second requirement in that only what are felt to be "probable" trouble spots are protected, and, secondly, the monitoring devices are again commerical type relays connected to the output terminals of various power supplies in the system. In this case the supplies are located in each of the servo amplifiers which control the axial drive hydraulic valves. In each amplifier there are two negative voltage supplies which, if either of them failed, would result in the model strut driving to the forward limit of its travel. To prevent this from happening the contacts of the monitoring relays are used to apply a negative signal to the hydraulic valve if the supply fails thus causing the strut to move rearward rather than forward.

Once again there is no protection for partial voltage loss or over voltage type failures. However, at worst, these failures only cause sluggish response of the particular model strut concerned and, at best, produce the same effect that the safety system is asked to produce, i.e., move that model strut to the rear axial position. Also this system again does not offer 100% protection because there are components which cannot, within reasonable limits, be monitored continuously.

4. The ability to remove models from the arc-jet flow is derived from the model programming system used to control the operation of the entire model carriage system. These devices control all activities of both the lateral and axial drive systems. To remove the model from the flow test section requires only that the programming devices be advanced prematurely through those steps which maintain the particular model in question in the test position. To do this requires a false stepping signal from an external, operator-controlled source which will be

interpreted by the device as its own self-generated stepping signal. At present that external source is a unijunction transistor monostable oscillator circuit. The output pulse from this circuit is applied to the stepping circuitry in each of the control programmers causing the unit which is active at the instant to advance one step past the last pinning step. The timing device controls all the necessary hydraulic and electrical commands to remove the model from the gas flow field.

SECTION X

CONCLUSIONS

The work completed under this effort has been that of taking a prototype model support system and refining it to allow efficient daily operation. The improvements have helped to reduce the manpower as well as time required to set-up and operate the model support system. It has also increased the reliability, which has greatly reduced the chances of improper operation and therefore the loss of data. Along with these improvements a new mode control, the ramp mode, was added to increase the testing capability of the RENT Facility.

APPENDIX A

OPERATING PROCEDURES FOR AXIAL DRIVE SYSTEM

A. Preliminary operating instructions: (Each item should be checked off on data sheet 1 as it is completed.)

1. Be sure all personnel working on or around the carriage know that the axial drive or lateral carriage system is being turned ON.

2. Turn on the axial drive electronics <u>before</u> turning on the hydraulic pumps. (This prevents the axial drive struts from drifting or jumping around and possibly damaging models.)

3. Check to see that the axial drive amplifier (Moog's) currents are zero. If they are not, adjust the position pots until they are.

4. The hydraulic pumps may now be turned on.

5. When shutting down the axial drive system keep the electronics turned ON. Turn OFF the hydraulic pumps and allow the hydraulic pressure to go to zero. Check for zero pressure on the Main Accumulator (PHMC) gage behind the RENT carriage to make certain it is zero. (This prevents the possibility of the meter amplifier in the control room from having been turned OFF and thus giving a zero indication on the Axial Drive Panel in the control room.) After the hydraulic pressure is zero, the electronics can be turned off. The order of shut down is important for the same reason as in Part A-2.

B. The following checks should be made before each test series or approximately every two weeks, although not necessarily in the order shown. Each item should be checked off on data sheet 1 as it is completed.

1. During alignment of the models or if the heat sensors are disconnected from their mount, disconnect the galvanometer drivers for the galvanometers involved, by switching to the calibrate position on oscillograph #4 switch panel. This will keep from damaging the galvanometers. Also when the heat sensors are disconnected, the sensor amplifiers should be turned off to keep the amplifiers from being driven at full power (saturation) for long periods of time.

2. Check the calibration of the panel mounted digital voltmeter (DVM). Use switch position #0 (See Table I) to check the zero. This position shorts the input leads of the DVM. Use switch position #9 and input a voltage from a voltage standard to the input jack on the front panel, to check the DC voltage calibration of the meter. If the readings are incorrect pull the front cover off and adjust the trim potentiometer for the correct zero and voltage readings. When the calibration is complete check off the item on data sheet 1.

3. Check the calibration of the axial position readouts.

a. Check the calibration of each strut and record the value on data sheet 2.

b. Recalibrate each strut by adjusting the span control of the bridge conditioner used with that strut. (1 inch of travel should equal 1.000 volt.)

c. Record the new calibration on data sheet 2.

4. Check the galvanometer calibrations for oscillograph #4.

a. Using data sheet 2, check the following traces by putting in a signal from the battery powered calibrate box or by patching it from the instrumentation voltage standard switch panel to the input of the oscillograph and then switching in the appropriate channels.

b. Record the deflection for a certain input value, for those galvanometers listed. Readjust any that are not correct and record the corrected values. (The listed calibration values are general and may be different for individual tests.)

c. The galvanometer traces should then be aligned across the paper as shown in Table V.

5. Check the gains of heat sensor amplifiers 1, 2, and 3.

a. Disconnect the coaxial cables, coming, from the heat sensor bridges, from the heat sensor amplifier case.

b. Set the gain switch for heat sensor amplifiers 1, 2, and 3 to low (L).

c. Connect the four inputs to ground and zero the output of amplifiers 1 and 2 using the panel DVM (use Tables I and II for setting the switches to read the outputs on the DVM).

d. Input 1.0 volt to the positive input connector of amplifier 1 and 2 and record the gain on data sheet 2.

e. If either value is incorrect readjust the gain for the correct value (values are given on data sheet 2) and record on data sheet 2.

f. Adjust the gain control dial of heat sensor amplifier 3 to 2.00 and record the value on data sheet 2.

g. Reconnect the coaxial cables to the heat sensor amplifier case, making sure the cable and connector numbers match. (<u>This item is of extreme importance to insure the proper polarity</u>.)

6. Check the arc abort system.

a. Check to see carriage is in home position (south) and safety pinned (arc abort disarmed in north position).

b. Place the #1 programmer timer (Agastat) into step #1.

c. Operate the arc abort switch located on the front panel. The arc abort light located next to the switch should go out and buzzer should sound.

d. Reset the system by switching the 60-Hz switch off and on. The arc abort should come back on.

e. Check off item on data sheet 1 when you are finished.

7. Check the single strut abort system.

a. CAUTION: MAKE SURE HYDRAULIC PRESSURE IS ZERO.

b. Turn on all three programmable timers (Agastat).

c. Check to see that the pin lock switch is in the OFF (pin) position.

d. For proper operation the system should work as follows: When the programmable timer switches to the step tha[illegible] ides the pinning signal (activates the pin load), the pin signal normally remains activated for the time set on the timer. When the single strut abort switch is activated, the programmable timer immediately steps the number of steps necessary to be in the first step where the pin load is no longer activated.

e. When this check has been made, check off item on data sheet 1.

8. Check the five servo amplifiers (Moog amplifiers) gains* and bias settings.

*NOTE: If the individual heat sensor gains are advanced or decreased by more than 50% due to special test considerations the offset voltage must be changed proportionally by the amount the gains are changed. If only one heat sensor gain is changed a large amount, consult special instructions paragraph H to be found later in this section, Appendix A.

a. CAUTION: MAKE SURE THE HYDRAULIC PRESSURE IS ZERO.

b. Set all of the servo amplifier heat sensor gain control dials to the values listed in Table IV.

c. Set the offset voltage to zero (DVM switch position 6).

d. Adjust the heat sensor amplifiers zero control for a zero output. (DVM switch position 8; sensor amplifier switch positions 1 and 2.)

e. Turn on the manual heat sensor control switch located on individual mode controller unit being checked.

f. Using the heat sensor amplifier's zero controls adjust the servo amplifier current meter for a reading of plus (+) 10 milliamps.

g. Record the voltage reading of the DVM (DVM switch position 7) on data sheet 2 and compare it to the values in Table IV. If they do not match, adjust the servo amplifier (Moog amplifier) internal gain control for the proper value of current for the given voltage input.

h. Turn off the manual heat sensor control switch.

i. Connect the panel DVM externally to terminal #18 on the terminal strip on the rear of the servo amplifier to be checked.

j. Set the heat sensor output and offset for zero output.

k. Turn on the manual heat sensor control switch again.

l. Using a screwdriver, adjust the bias control located on the front panel of the servo amplifier for a zero output reading on the DVM.

m. Turn off the manual heat sensor control switch.

n. Remove the external connection to the servo amplifier terminal strip.

o. Repeat steps a - n for the other 4 servo amplifiers.

p. Follow the operating instructions and have the hydraulic pumps turned on.

q. Axially position a strut in the center of its travel.

r. With the heat sensor output and offset still set to zero, manually switch a heat sensor control.

s. By reading the position readout on the DVM, adjust the bias control to stop the movement of the strut. (CAUTION: Be sure the mechanism is not mechanically stopped at either end of travel.)

t. Repeat steps p - s for the other 4 servo amplifiers.

C. The following checks are to be made before each run. (Check the following items off of data sheet 3 as they are completed.)

1. Check the glass covering over the heat sensors and clean.

2. Check every third run or as required, the output of the heat sensors at the RENT carriage.

a. Place the calibration light fixture on top of the heat sensor block.

b. Connect to 24 volt DC power supply to fixture.

c. In the control room, set heat sensor amplifier #1 and #2 to medium gain (M).

d. Set the DVM switch to position #8.

e. Set the heat sensor amplifier case switch to the amplifier being used for the check.

f. Record the output values on data sheet 3 of amplifiers #1 and #2 for the lights being off and on for sensors #2 and #3.

g. Read the output of the Brown-Edwards light sensor (LSBE) from the instrumentation system DVM and record it on data sheet 3.

3. After all the models have been aligned and set up at 0.0 inch from the nozzle exit plane, the readout voltage for each strut has to be adjusted to zero. Set the DVM position switch to the proper strut number and adjust the balance control of the bridge conditioner for a zero output reading on the DVM.

4. To set and record the gain of heat sensor amplifier #3 use Table III. From the Por (Rear orifice pressure in arc heater, PSIA) and the type of nozzle to be used for the run, determine the proper gain. (Other circumstances may require higher or lower gain settings, such as the expectation of high ablation rate from a material not previously tested.) Record this setting on data sheet 4.

5. The normal servo amplifier heat sensor gain is checked at the start of any test series (see paragraph B8). Check each of the 5 dial settings for the correct values. (Special circumstances may require one or more dials to be set at values determined for various model materials used.) Record this setting on data sheet 4.

6. Set the heat sensor comparator level as follows:

a. CAUTION: MAKE SURE THE HYDRAULIC PRESSURE IS ZERO.

b. From the Run Sheet determine if one or two heat sensor levels are required.

c. If only one level is required use heat sensor amplifier 1 zero control to input the appropriate positive voltage.

d. Switch one of the model positions to manual heat sensor control.

e. Adjust the low level trim pot, until the heat sensor light comes on.

f. Using the heat sensor reset button and the offset make sure the heat sensor light comes on as you reach the appropriate voltage level.

g. For two levels adjust the lower value level as in steps c - f.

h. For the high level, pull-in the comparator level relay on the Agastat patch panel.

i. Adjust the high level trim pot, repeating steps c - f.

D. The following checks are to be made before each cold blow. (Approximately 1/2 hour to 1 hour before.)

1. Check to see that the three gain switches on the heat sensor amplifiers are set to low gain (center position).

2. Check to see that the galvanometer drivers used with the oscillograph are switched ON.

3. Set the offset for a (minus) -.075 volts.

4. Read and record on data sheet 4 the heat sensor cooling water temperature (TWHS) from the panel meter.

E. The following checks are to be made immediately (approximately 2 minutes) before the cold blow.

1. Check to see all model positions are zero or at proper setting (DVM readout, DVM switch positions 1 - 5).

2. Set the heat sensor amplifiers output to zero by adjusting zero dial on amplifier #1 and #2.

3. Make sure the DVM position switch is set to #7 position. (This keeps noise off of the inputs to the servo amplifiers.)

F. The following checks are to be made between the cold blow and hot run.

1. Check the oscillograph data taken during the cold blow to assure that the parameters to be recorded appear correctly. Note any necessary changes made on data sheet 3 under comments.

2. Change the offset polarity switch to plus (+) .035 volts.

G. The following checks are to be made immediately (approximately 2 minutes) before the hot run.

1. Check to see all model positions are zero (DVM readout, switch positions 1 - 5).

2. Set the heat sensor amplifier output to zero by adjusting zero dial on amplifier #1 and #2.

3. Make sure the DVM position switch is set to #7 position.

H. Special models may require the servo amplifier gain to be set considerably higher or lower than normal. (Greater than 50% change.) This can be accomplished several ways depending upon the number of models requiring the special gain. The following methods are used to keep the offset constant.

1. Condition 1: All models require the same special gain. The third heat sensor amplifier gain is adjusted by the percentage of change required by the special models. The same offset values as normal are used. (The offset value remains uneffected because the gain change takes place before it is added).

2. Condition 2: One or two models require one special gain. The servo amplifier gains of the models requiring the special gain must be changed. This effectively changes the offset voltage by amplifying it proportionately. To keep the offset constant it is necessary to cancel out the effective change by adding or subtracting this voltage with a special offset box (see Figure 24). A separate offset box is required for every special gain setting used.

3. Condition 3: Three or four models require one special gain.

a. Adjust the third heat sensor amplifier gain proportionately for the three or four models.

b. The remaining one or two models require that the servo amplifier gain be changed to compensate for the third heat sensor amplifier change to return the overall gain to the normal value. In addition a special offset box will be required to compensate for the servo amplifier gain changes to keep the offset constant.

4. On Cold Blow: Because the special offset box is not normally polarity switched between the cold blow and hot run, the normal offset box should be adjusted appropriately for the cold blow to move the struts to the rear but not at a high enough rate of speed to damage the struts. This means that if the sum of the special offset box and the normal offset value of -.075 MV is a positive number, the normal offset will have to be set more negative. This value should be set to give a sum of -.020 MV. This will be enough to drive the special gain struts to the rear. This should also keep the normal gain struts which are only seeing the normal negative offset from driving back too hard against the rear stops.

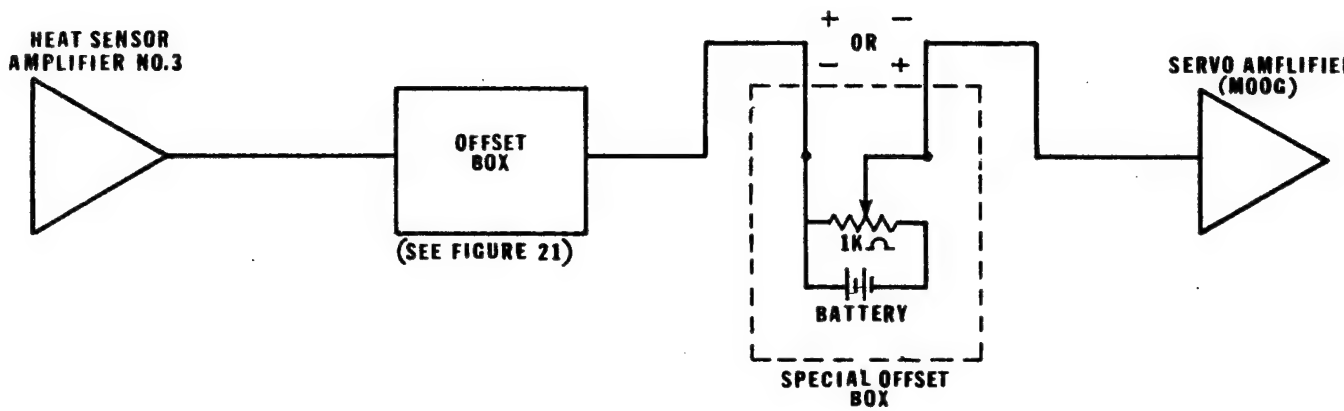


Figure 24 SPECIAL OFFSET BOX

AFFDL JON ____________

TEST NUMBER ____________

STARTING DATE____________

DATE										
A. AXIAL DRIVE OPERATING INSTRUCTIONS										
1. Carriage Area Clear										
2. Electronics Turned ON										
3. Currents Zero										
4. Hydraulics Turned ON										
5. Shutdown Procedure										
B. CHECKS BEFORE EACH TEST SERIES (2 WEEKS)										
1. Protect Galvonometers & Heat Sensor Amps										
2. Calibrate DVM										
3. Calibrate Axial Position Readouts										
4. Calibrate Oscillograph										
5. Check Heat Sensor Amp Gains										
6. Check Arc Abort System										
7. Check Single Strut Abort System										
8. Check Servo Amp Gains										

COMMENTS:

DATA SHEET 1

POSITION NUMBER	BEFORE CALIBRATION	AFTER CALIBRATION	NOMINAL VALUES
1			1 Volt of Output/1" of Travel
2			1 Volt of Output/1" of Travel
3			1 Volt of Output/1" of Travel
4			1 Volt of Output/1" of Travel
5			1 Volt of Output/1" of Travel

AXIAL POSITION READOUT CALIBRATION

	BEFORE	AFTER	NORMAL	RAMP MODE
Heat Sensor Amplifier #1			100mv/1"	100mv/1"
Heat Sensor Amplifier #2			200mv/1"	200mv/1"
Heat Sensor Amplifier #3			100mv/1"	100mv/1"
Axial Position #1			1 Volt/5"	1 Volt/1"
Axial Position #2			1 Volt/5"	1 Volt/1"
Axial Position #3			1 Volt/5"	1 Volt/1"
Axial Position #4			1 Volt/5"	1 Volt/1"
Axial Position #5			1 Volt/5"	1 Volt/1"

OSCILLOGRAPH CALIBRATION

	Gain Before Correction	Gain After Correction	Normal
Heat Sensor Amplifier #1			1 ±.010
Heat Sensor Amplifier #2			6 ±.010
Heat Sensor Amplifier #3			-10 ±.010

HEAT SENSOR AMPLIFIER GAIN SETTINGS

SERVO AMPLIFIERS	GAINS	NORMAL VALUES	DIAL READING
1	______ MV Input/+10ma Output	911±15 mv/10ma	303
2	______ MV Input/+10ma Output	700±15 mv/10ma	464
3	______ MV Input/+10ma Output	737±15 mv/10ma	456
4	______ MV Input/+10ma Output	674±15 mv/10ma	483
5	______ MV Input/+10ma Output	762±15 mv/10ma	452

SERVO AMPLIFIER GAINS (MOOG AMPLIFIERS)

DATA SHEET 2

AFFDL JON	________
TEST NUMBER	________
DATE	________

C. CHECKS BEFORE EACH RUN	
1. Check & Clean HS Glass	
2. HS Output (Every 3rd run)	
3. Adj. Pot Readout Conditioner	
4. Set Gain of 3rd HS Amp	
5. Check Servo Amp Gain Dial	
6. Set HS Comparator Level	

D. CHECKS BEFORE COLD BLOW (½ to 1 HR)	
1. HS Amps Gain Switches Low	
2. Galvo Drivers On	
3. Offset Set to -.075v	
4. Record HS Cooling Water Temp	

E. CHECKS BEFORE COLD BLOW (2 Min)	
1. Model Positions Set Properly	
2. Adjust HS Amps 1 & 2 to Zero	
3. DVM Set at 7	

F. CHECKS BEFORE HOT RUN	
1. Check Oscillograph Data	
2. Offset Set to +.035v	

G. CHECKS BEFORE HOT RUN (2 Min)	
1. Model Positions Set Properly	
2. Adjust HS Amps 1 & 2 to Zero	
3. DVM Set at 7	

COMMENTS:

DATA SHEET 3

AFFDL JON ________

TEST NUMBER ________

DATE ________

1. HEAT SENSOR OUTPUT FROM CALIBRATE LIGHT

Brown-Edwards Sensor, LSBE ________ MV 20 - 60 MV Standard

2 Sensor & 1 Amp, Gain = Med ________ MV 18 - 22 MV Standard

3 Sensor & 2 Amp, Gain = Med ________ MV 30 - 42 MV Standard

2. GAIN SETTING OF 3RD HS AMP. ________

3. SERVO AMPLIFIER HEAT SENSOR GAIN DIAL SETTING

#1 ________________ (303 Standard)

#2 ________________ (464 Standard)

#3 ________________ (456 Standard)

#4 ________________ (483 Standard)

#5 ________________ (452 Standard)

4. HEAT SENSOR COOLING WATER TEMP ________ °F (75 - 80° Standard)

COMMENTS:

DATA SHEET 4

AFFDL JON ____________

TEST NUMBER ____________

DATE ____________

1 Determine Ramp Time	
2 Set Dials	
3 Determine Ramp Voltage	
4 Set Range Switch	
5 Set Rear Model Position	
6 Adjust Ramp Controls on Servos	
7 Check Oscillograph Data	

$$\text{Total Ramp Time (sec)} = \frac{\text{DISTANCE (IN)}}{\text{VELOCITY (IN/SEC)}}$$

MODEL	DISTANCE TO RAMP	RAMP VELOCITY	TOTAL RAMP TIME	DIAL SETTING	
1					
2					
3					
4					
5					

Range Switch Setting __________ (0 - 9)

COMMENTS:

DATA SHEET 5

Switch Position	Purpose
0	Shorts Input to DVM for Zero Check
1	Axial Position Readout for Strut 1
2	Axial Position Readout for Strut 2
3	Axial Position Readout for Strut 3
4	Axial Position Readout for Strut 4
5	Axial Position Readout for Strut 5
6	Offset Voltage
7	Offset Voltage + 3rd Sensor Amplifier Voltage
8	Sensor Amplifier Case, Switch
9	Connects to Jacks on Front Panel

TABLE I

DIGITAL VOLTMETER SWITCH POSITIONS

Switch Position	Purpose
1	Heat Sensor Amplifier Output 1
2	Heat Sensor Amplifier Output 2
3	Heat Sensor Amplifier Output 3
4	
5	
6	
7	
8	
9	
10	
11	

TABLE II

SENSOR AMPLIFIER CASE, SWITCH POSITION

POR (PSIA)	80% .9-1.1P .9-1.38F	65% .9-1.32P	50% .9-1.49P	40% .9-1.7P	20% .9-2.39P
1800	1.80	1.95	2.15	2.25	2.45
1500	2.00	2.05	2.25	2.40	2.55
1100	2.15	2.25	2.40	2.45	2.65
900	2.25	2.40	2.45	2.55	2.75
700	2.40	2.45	2.55	2.60	2.80
370	2.55	--	--	--	--

TABLE III

HEAT SENSOR GAIN CHART (AMP. #3 DIAL SETTINGS)
NOZZLE RECOVERY

	POSITION GAIN	HEAT SENSOR GAIN		
Number	Current Output / Voltage Input	Current Output / Voltage Input	Current Output / Voltage Input	Dial
1	16ma/500mv	8ma/730mv	10ma/911mv	303
2	16ma/500mv	10.5ma/730mv	10ma/700mv	464
3	16ma/500mv	10ma/730mv	10ma/737mv	456
4	16ma/500mv	11ma/730mv	10ma/674mv	483
5	16ma/500mv	9.5ma/730mv	10ma/762mv	452

TABLE IV

SERVO AMPLIFIERS STANDARD GAIN SETTING

	AXIAL POSITIONS OF STRUTS					HEAT SENSORS AMPLIFIERS		VALUE PILOT PRESSURES				LATERAL CARRIAGE POSITION (NP1)	Comparator ON	HEAT SENSOR AMPLIFIER	PRESSURE HYDRAULIC MAIN CARRIAGE (PHMC)	PRESSURE HYDRAULIC MAIN CARRIAGE BACK (PHMCB)	LOAD INDICATORS				
	1	2	3	4	5	1	2	P1	P2	P6	P7			3			1	2	3	4	5
GALVANOMETER DRIVER	1	2	3	4	5	6	7	9	10	11	21	13	12	8	14	15	16	17	18	19	20
GALVANOMETER NUMBERS	1	2	3	4	5	6	7	9	10	11	27	13	12	8	20	21	22	23	24	25	26

NOMENCLATURE OF TRACES	Input Voltage To Drivers	Travel of Galvanometer	
Axial Position of Struts (1-5)	1 Volt	5 Inches*	1 Inch of Axial Travel
Heat Sensor Amplifier 1 & 3	100 mv	1 Inch	
Heat Sensor Amplifier 2	200 mv	1 Inch	
Valve Pilot Pressures P1, P2, P6, P7	1 Volt	1 Inch	200 PSI
Lateral Carriage Readout (NP1)	1 Volt	.25 Inch	(Not Critical)
Pressure Hydraulic Main Carriage (PHMC)	1 Volt	1 Inch	1000 PSIG
Pressure Hydraulic Main Carriage Back (PHMCB)	1 Volt	.5 Inch	500 PSIG
Load Indicators (1 - 6)		.25 Inch	(Deflection When Tunnel ON)
Comparator ON	1 Volt	.10 Inch	

*This value is 1 inch for the ramp mode.

TABLE V

AXIAL DRIVE OSCILLOGRAPH CALIBRATION AND POSITIONING

APPENDIX B

MAINTENANCE AND TROUBLESHOOTING

There is no scheduled maintenance period for the electronic equipment. The only small exception is the requirement to replace the three mercury cells located in the heat sensor junction box at 18 month intervals. The wiring on the lateral carriage should be inspected from time to time for heat and mechanical damage.

Safety precautions must be observed when operating or troubleshooting this equipment as large hydraulic pressures and mechanical forces may exist. Always follow the operating procedures as outlined in Appendix A.

Whenever problems with the axial positioning systems are suspected, make sure the problem is indeed the axial positioning system and not a programming error. If the axial positioning system operates in a normal manner when manual commands are given, the fault is almost always either a programming error or a program equipment malfunction. If the problem is in the positioning system one of the most suspected locations for problems is the model carriage. All wiring and devices mounted around the carriage should be checked for heat or mechanical damage.

One mechanical problem which can occur is one which causes a small shift in the model position when transferring from the position mode to the heat sensor mode. The probable cause of this type of shift is a loose position potentiometer wiper rod connection to the axial carriage or the hydraulic cylinder may be loose on its mounting base.

Since this equipment for the most part consists of a closed loop servo it is very difficult to troubleshoot with hydraulic pressure applied. Most electronic troubleshooting is best accomplished with the hydraulic system turned off. In this static mode, the input voltage to the summing junction on the servo amplifier can be measured and compared.

APPENDIX C

SAFETY SYSTEM FAILURE CHECK-OUT PROCEDURES

In case of a failure of the safety system, the following procedures should be followed to determine the trouble areas. (Use Figures 25 - 28).

1. Symptom: Annunciator number 41 on the power control console will not clear and all model struts are moved to the rear axial position.

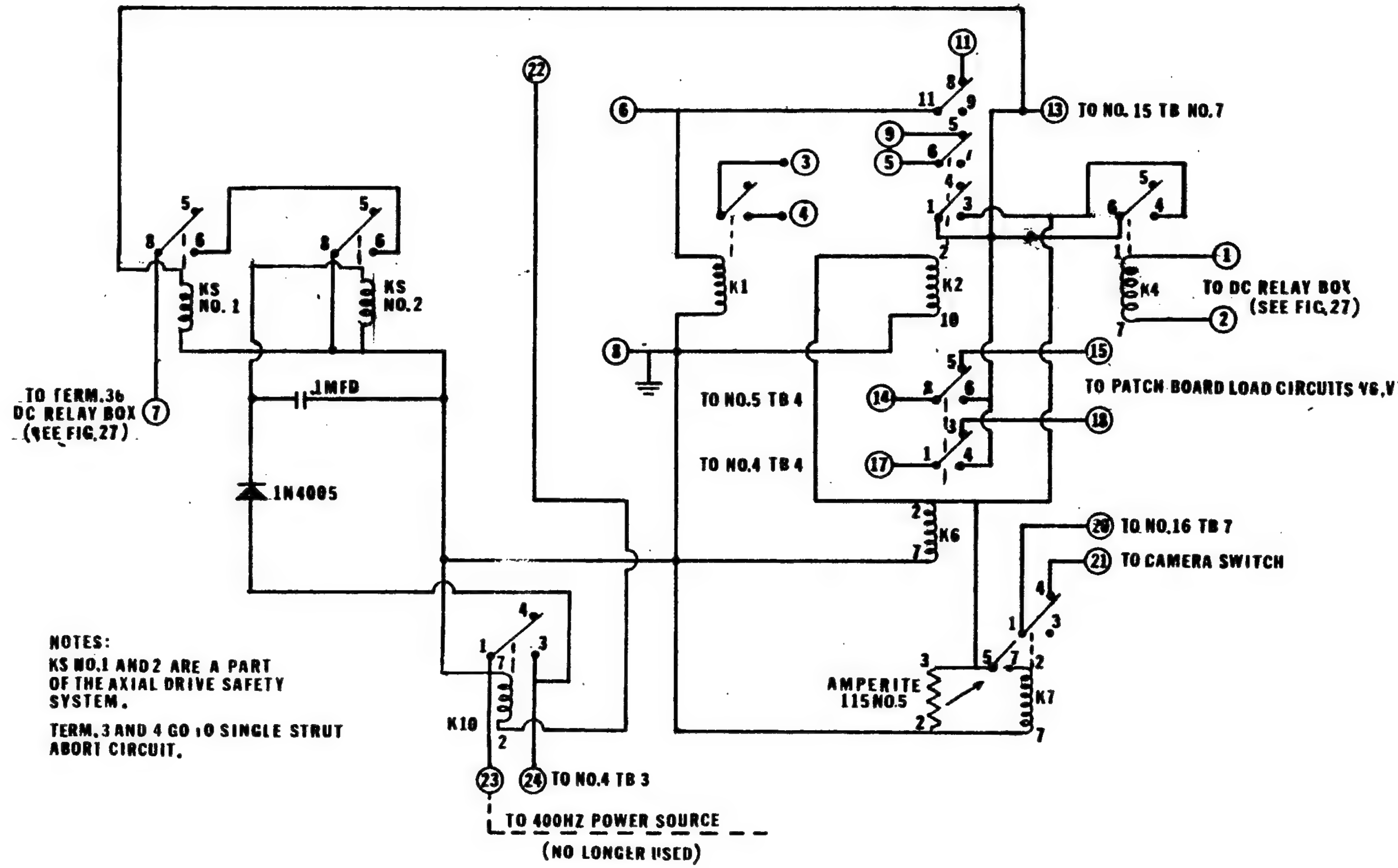
Check: a. Voltage between terminals 13 and 8 of the arc abort relay box should be 115 V, 60 Hz. If voltage reading is incorrect check system circuit breaker.

b. If axial drive system is in use, voltage from terminal 29 on the DC relay safety box to ground (terminal 2) should be 7.0 volts DC. If reading is incorrect check +5 volt power supply in the axial drive control units.

c. Voltage from terminal 31 of the DC relay safety box to ground (terminal 2) should be +24 volts DC. If reading is incorrect check +24 volt power supply in the axial drive control units.

d. Voltage from terminal number 30 to terminal number 36 of the DC relay safety box should be ≃ +12 V (terminal number 36 is ground). If voltage is incorrect, check the -15 V supply for the heat sensor amplifiers. If the supply is operating properly the main power switch for the axial drive system should be checked. The -15 V is routed through this switch to terminal 30.

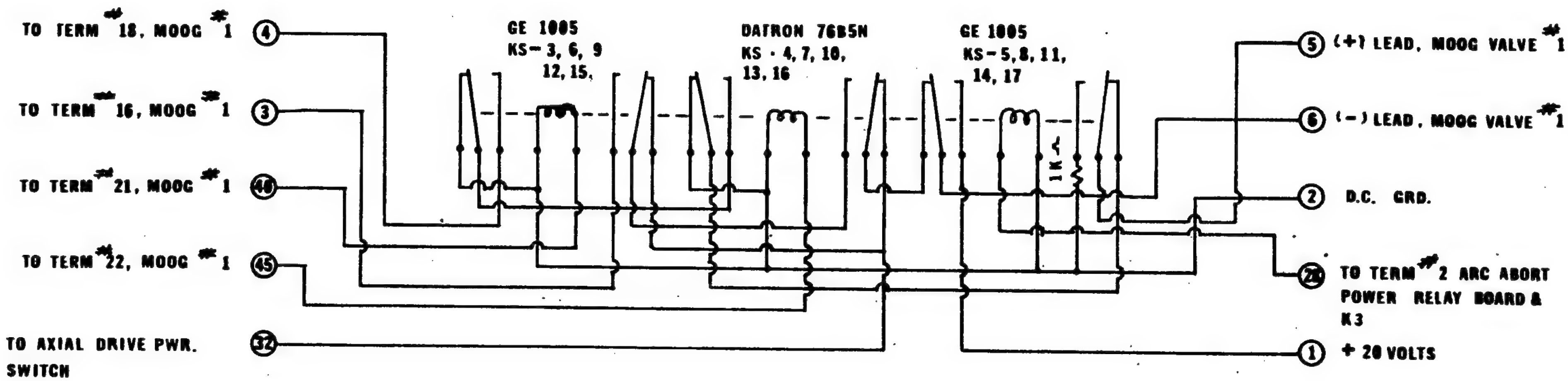
e. If the axial drive system is not in use, voltage from terminal number 50 to terminal number 36 on the DC relay safety box should be ≃ +12V (terminal number 36 in ground). If voltage is incorrect check the +20 V supply in the safety



NOTES:
KS NO.1 AND 2 ARE A PART OF THE AXIAL DRIVE SAFETY SYSTEM.

TERM.3 AND 4 GO TO SINGLE STRUT ABORT CIRCUIT.

Figure 25 ARC ABORT POWER RELAY BOX

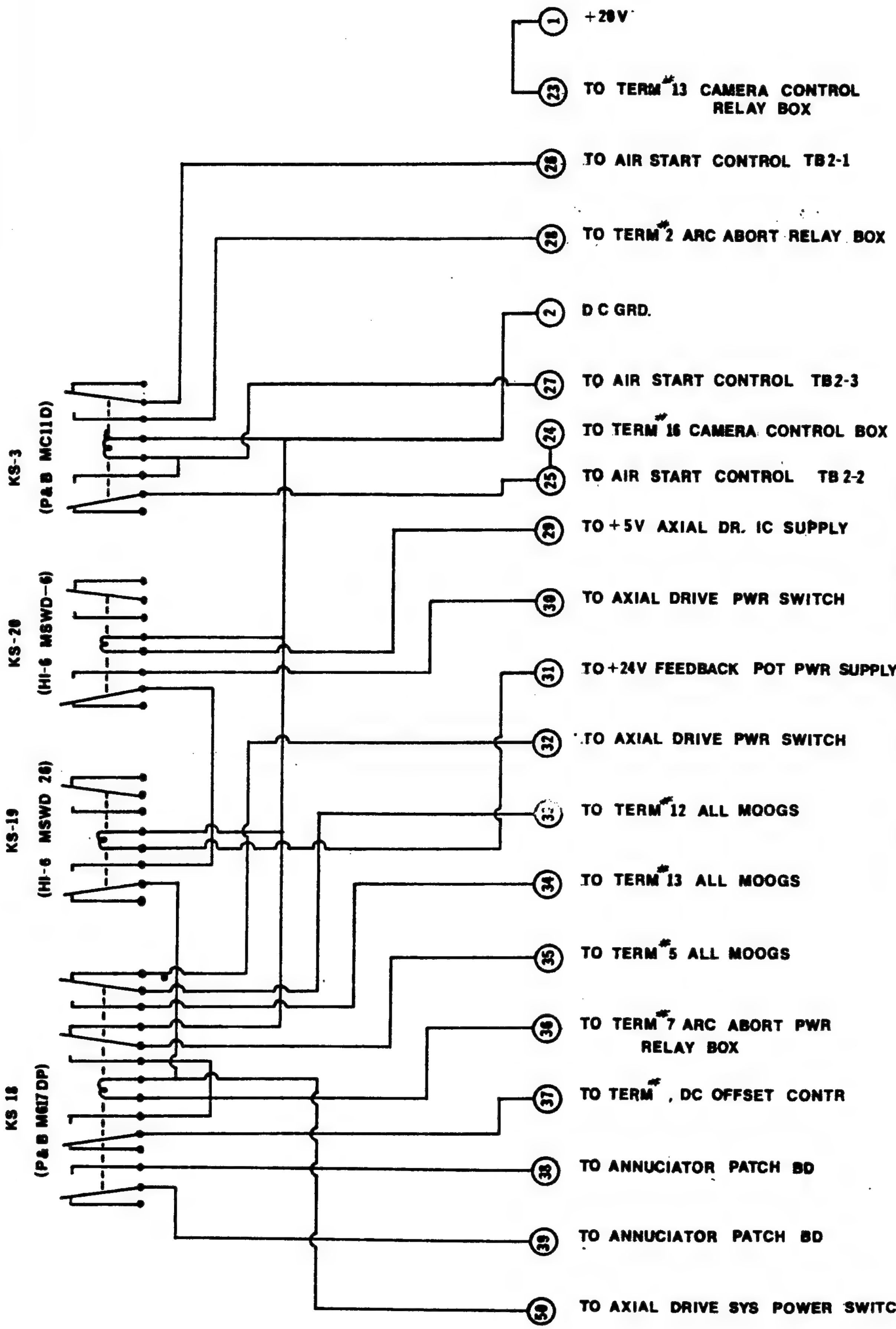


THIS WIRING DIAGRAM IS TYPICAL FOR ALL 5 STRUTS. TERMINALS CORRESPONDING TO THE OTHER MOOGS CAN BE FOUND IN THE TABLE BELOW.

MOOG TERMINAL	18	16	21	22	(+) LEAD	(-) LEAD
TO MOOG NO. 1	4	3	40	45	5	6
" " " 2	8	7	41	46	9	10
" " " 3	12	11	42	47	13	14
" " " 4	16	15	43	48	17	18
" " " 5	20	19	44	49	21	22

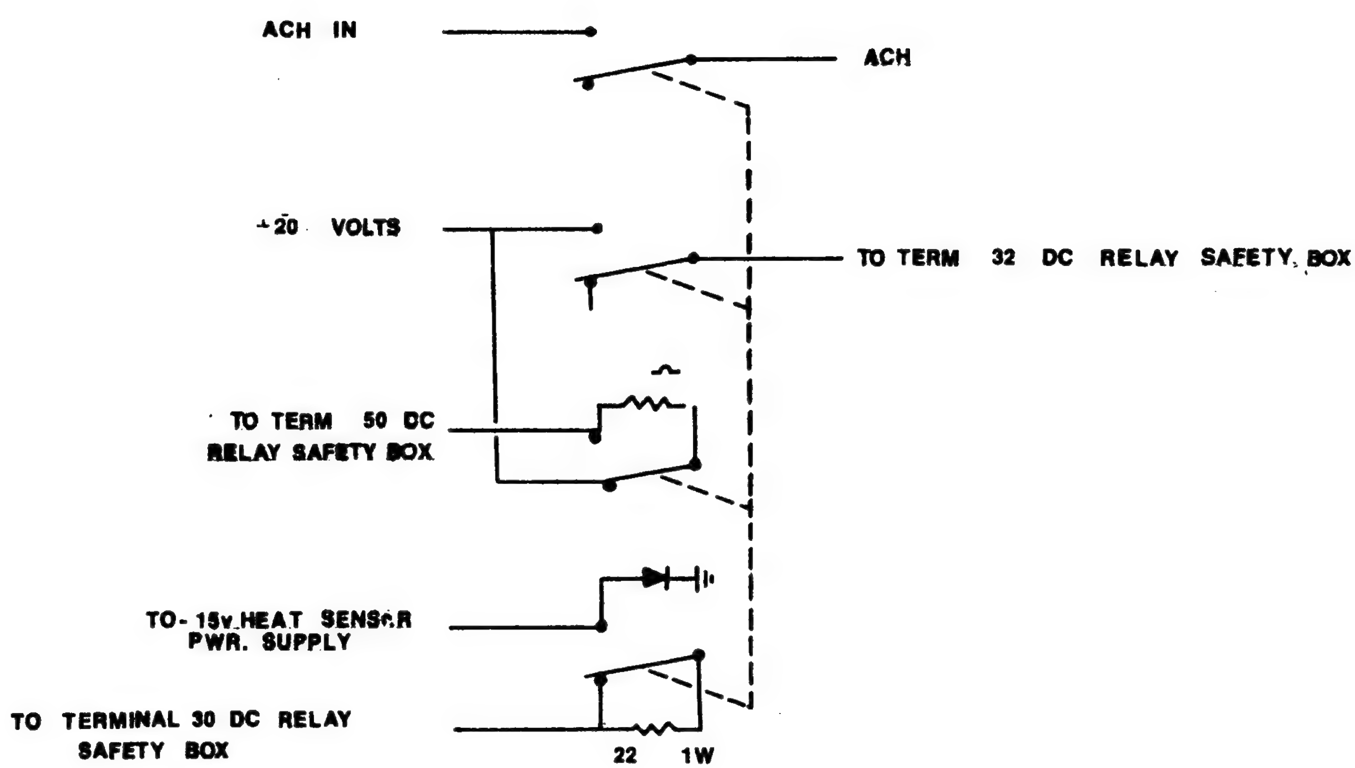
Location: D.C. Relay Safety Box

Figure 26. SAFETY SYSTEM RELAY WIRING (Sheet 1 of 2)



Location: D.C. Relay Safety Box

Figure 27 SAFETY SYSTEM RELAY WIRING (sheet 2 of 2)



SHOWN IN OFF POSITION

Figure 28 AXIAL DRIVE SYSTEM POWER SWITCH

system circuitry. If the supply is operating properly check the main power for the axial drive system. The +20 V is routed through this switch to terminal number 50.

f. If all the above checks do not isolate the problem area remove the leads from terminal 38 and 39 of the DC relay safety box and check the terminals with an ohm meter. If the terminals are shorted the problem is not in the safety circuits. If the terminals are open check that relays KS1, KS2, KS18, KS19 and KS20 are operating properly.

2. Symptom: All model struts are moved to the rear axial position, or the lateral carriage is locked in position, or both of these conditions previal.

Check: Facility abort system is not properly reset. The main 60 Hz power for the model carriage should be turned off and the +20 V power supply in the safety system should be turned off and then both turned on again. Indicator light on master control unit should be on. If system does not reset check relay K3, and the arming relay on model programmer number 1 (agastat) for proper operation. If these relays are operating properly check relays K2, K4 and K6 for proper operation.

3. Symptom: A single model strut is in the rear axial position and their is no apparent control of the strut by the Moog servo amplifier.

Check: Voltage at terminal 21 of the particular Moog amplifier involved should read -28 V to ground. Voltage at terminal number 22 of the Moog amp should read -15 V to ground. If these voltages are correct check that the same voltages are present at the appropriate terminals check the operation of the appropriate relays as shown by the circuit schematics.

4. Symptom: A facility arc abort occurs but the proper safetying actions fail to occur.

Check: Check that the safety system +20 V supply is operating. If so, check that +20 V is present at terminals 24 and 28 on the DC relay safety box. If not check the model programmer (Agastat) arming relay or relay K3 accordingly. Both relays should be energized. If only a single model strut does not move to the rear check that the appropriate relay (KS5, KS8, KS11, KS14, or KS17) is being energized and is operating properly. If the carriage fails to lock in position check that +20 V is present at terminal number 2 of the arc abort power relay box and that KS6 and KS7 are being energized and operating properly.

APPENDIX D

RAMP GENERATOR

The ramp generator is used to move the model forward axially at a constant velocity. This feature allows the simulation of atmospheric re-entry conditions. The ramp generator can move any strut forward or reverse at a constant velocity. The velocities of all five struts can be set separately.

A description of the ramp generator and control system follows. Control of the ramp generator is done thru the model programmer. The model programmer selects which unit is under ramp control, starts the ramp and resets it. The model programmer selects the model to be ramped by applying a 110 V AC signal to the proper select relay in the ramp control box (see Figure 30). This relay connects the ramp voltage from the ramp generator to the proper servo amplifier. It also provides a delayed start pulse to the ramp generator thru relay K6. R6 and C1 provide an RC time constant delay of approximately 300 milliseconds. When the 110 V AC signal from model programmer is removed the ramp generator receives a reset voltage level thru the select relay. The ramp rates for the five model positions are set via the five 3-decade voltage dividers (see Figure 29). The outputs of these voltage dividers go to an analog multiplexer. The same 110 V AC signal from the model programmer that is applied to the proper select relay is used via a special signal conditioner to select the proper multiplexer channel. The output of the multiplexer which is the value of the select voltage divider output, is the input of a voltage-to-frequency converter (VFC). The output of the VFC is the input to a 12-bit counter. The output of the counter drives a 12-bit digital-to-analog converter (DAC). The output of the DAC goes thru a range voltage divider to a buffer amplifier with a gain of one. The buffer amplifier provides a 10 milliampere current driving capability.

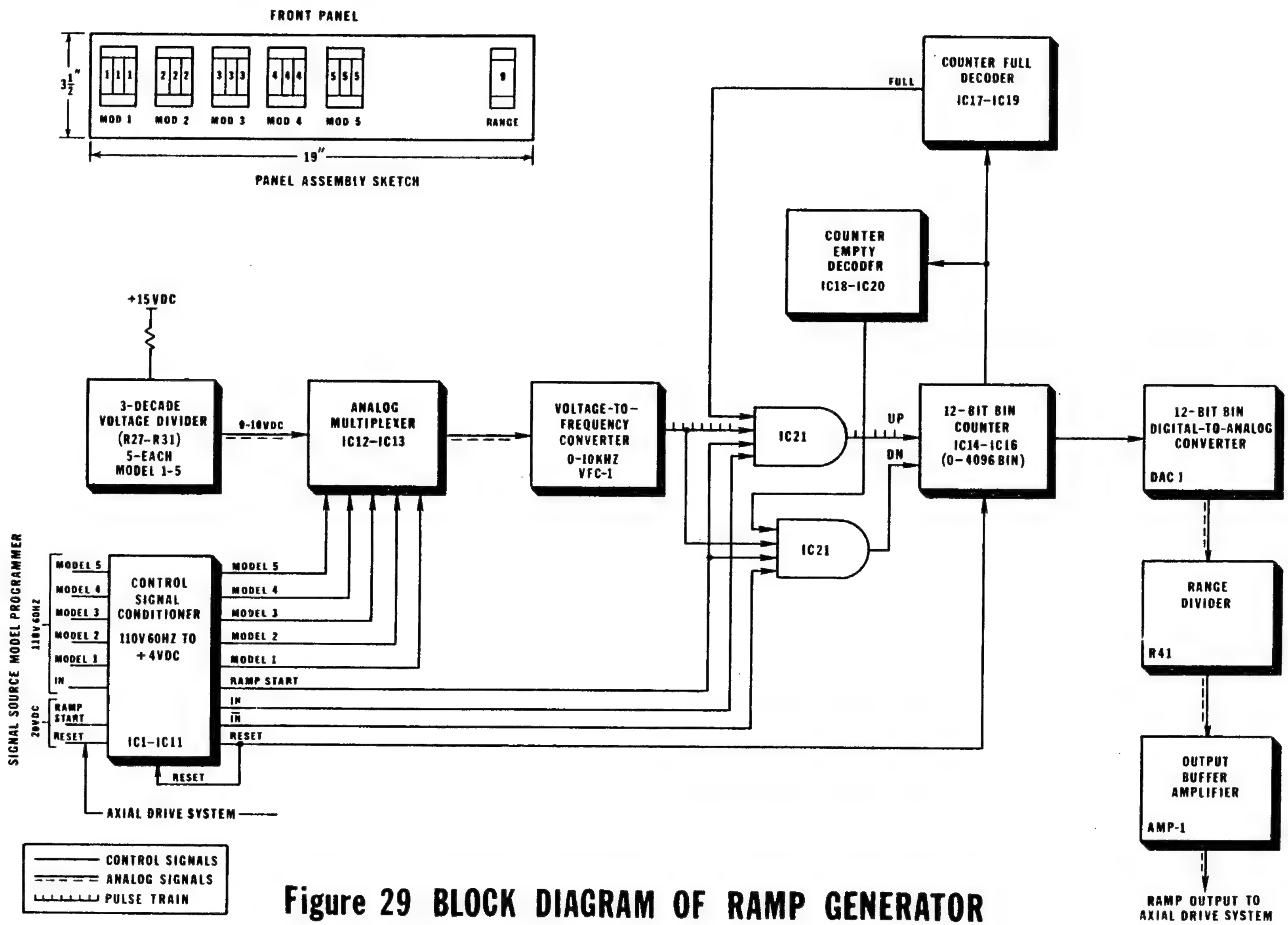
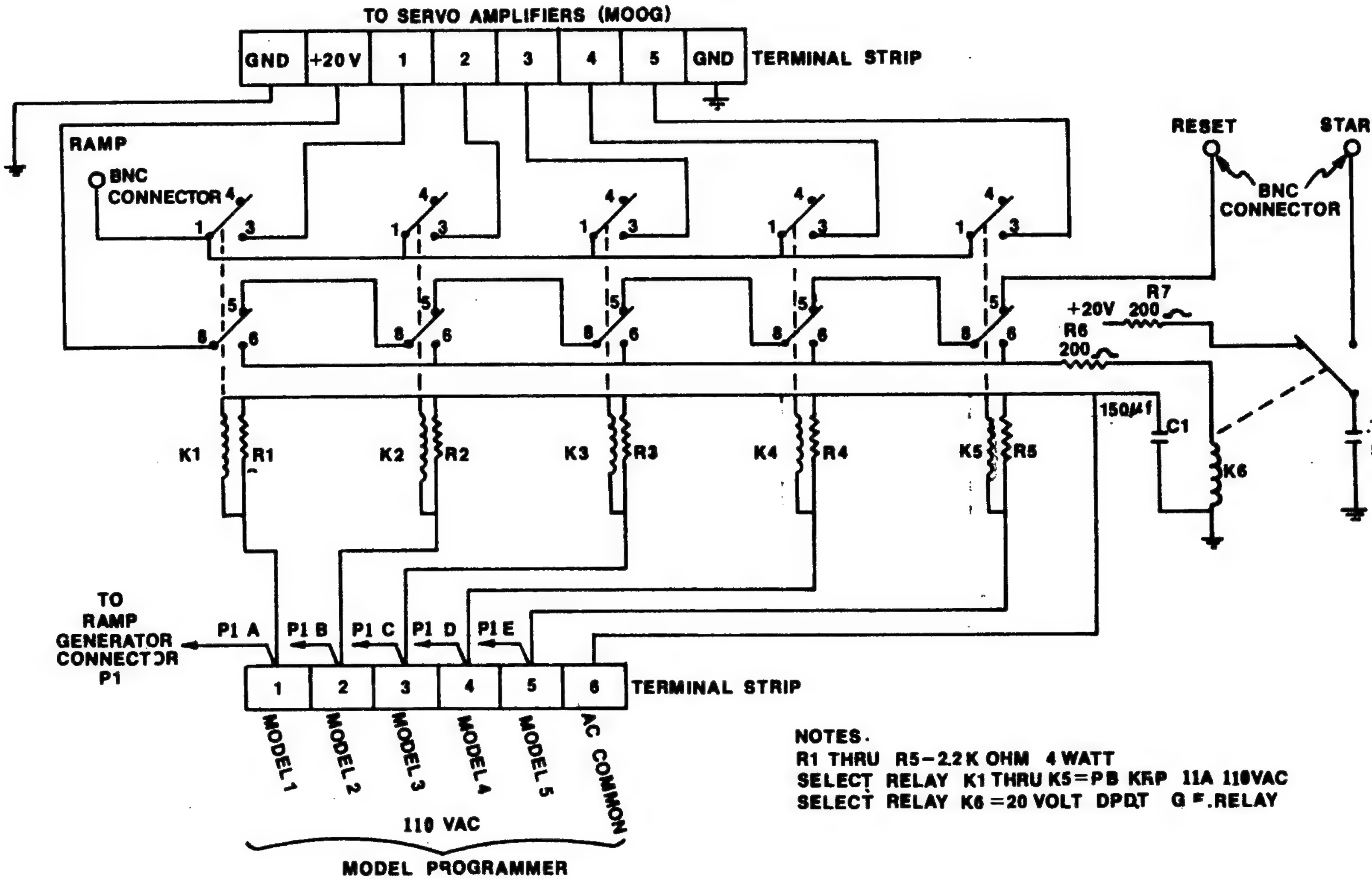


Figure 29 BLOCK DIAGRAM OF RAMP GENERATOR



NOTES.
R1 THRU R5–2.2K OHM 4 WATT
SELECT RELAY K1 THRU K5=PB KRP 11A 110VAC
SELECT RELAY K6 =20 VOLT DPDT G E.RELAY

Figure 30: RAMP CONTROL BOX

The output of the buffer amplifier goes to the ramp control box where it is connected to the proper servo amplifier via the select relays. Use Figures 30 - 33 for the following description. When a model is in the proper position the 110 V AC signal from the model programmer is used to activate one of the optical isolators IC 1-5. This sets one of the flip-flop networks IC 8-10 to hold the corresponding analog multiplexer channel (ICs 12-13) on. This causes VFC 1 to start oscillating at a frequency determined by the setting of the associated voltage divider, R28 - R32. After a 300 millisecond delay the ramp start signal (20 V DC) is received thru optical isolator IC 6 and sets the flip-flop network IC 24 which enables the up gate IC 21. The up gate, gates the VFC rate pulse into counters IC 14-16. The ramp will continue until the counter is full (10 V, that is 4096 counts). Upon reaching 4096, IC 17-19 will decode the full condition and disable the up gate. IC 25 provides a signal for recording when the counters are full. The ramp generator will remain in the full condition until the model is either ramped back or reset. To ramp back, the model programmer places a 110 V AC signal on IC23, another optical isolator. This sets the flip-flop network IC 10 which in turn activates the down gate also IC 21. This allows the VFC pulse to count down the counter IC A-16. ICs 17, 18 and 20 decode 0 and stop the counter. The ramp can be reset by removing the model programmer signals. This causes a reset signal to be sent to optical isolator IC 7 which being buffered by IC 11 resets counters IC 14-16 to 0.

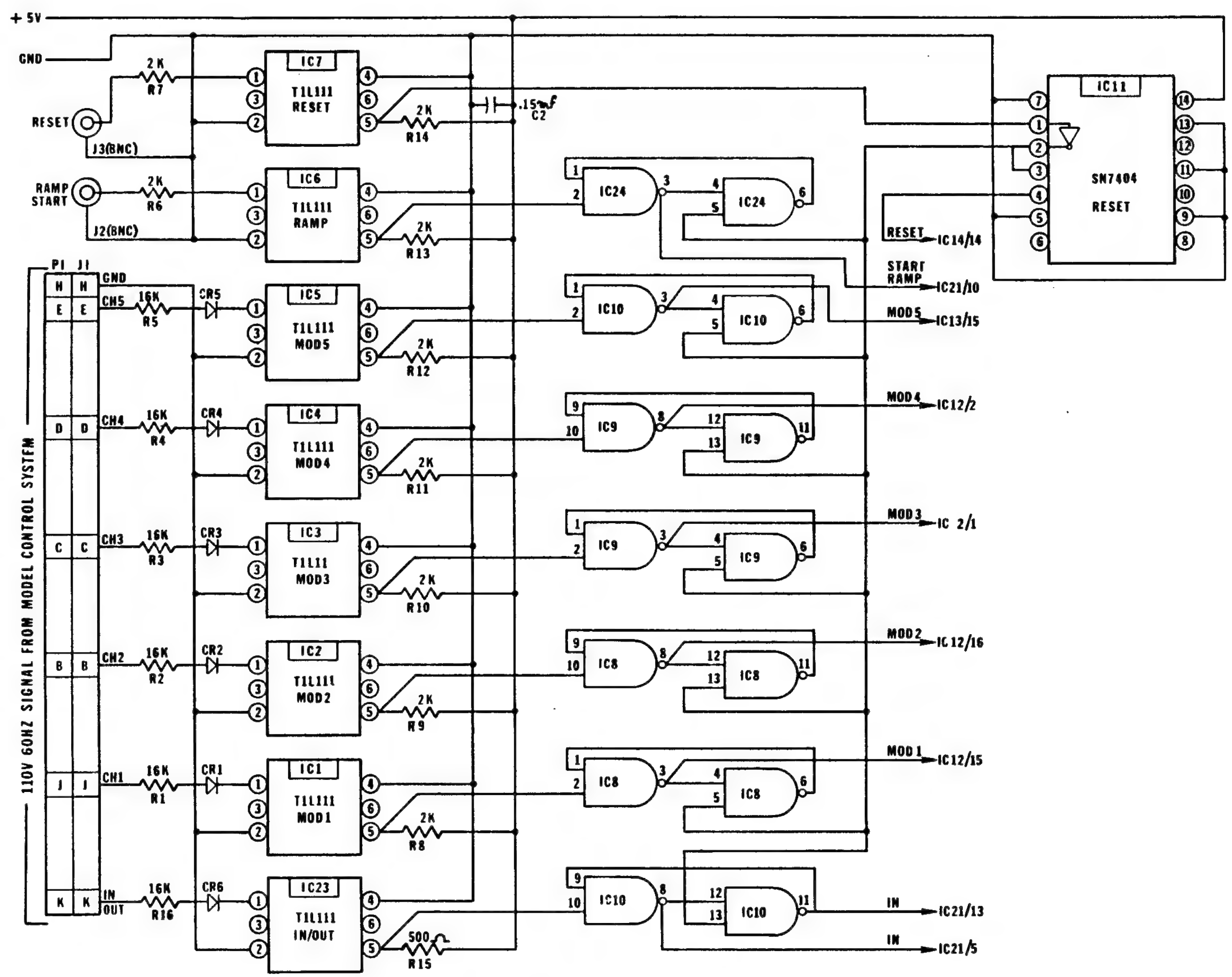


Figure 31 RAMP GENERATOR SCHEMATIC (Sheet 1 of 3)

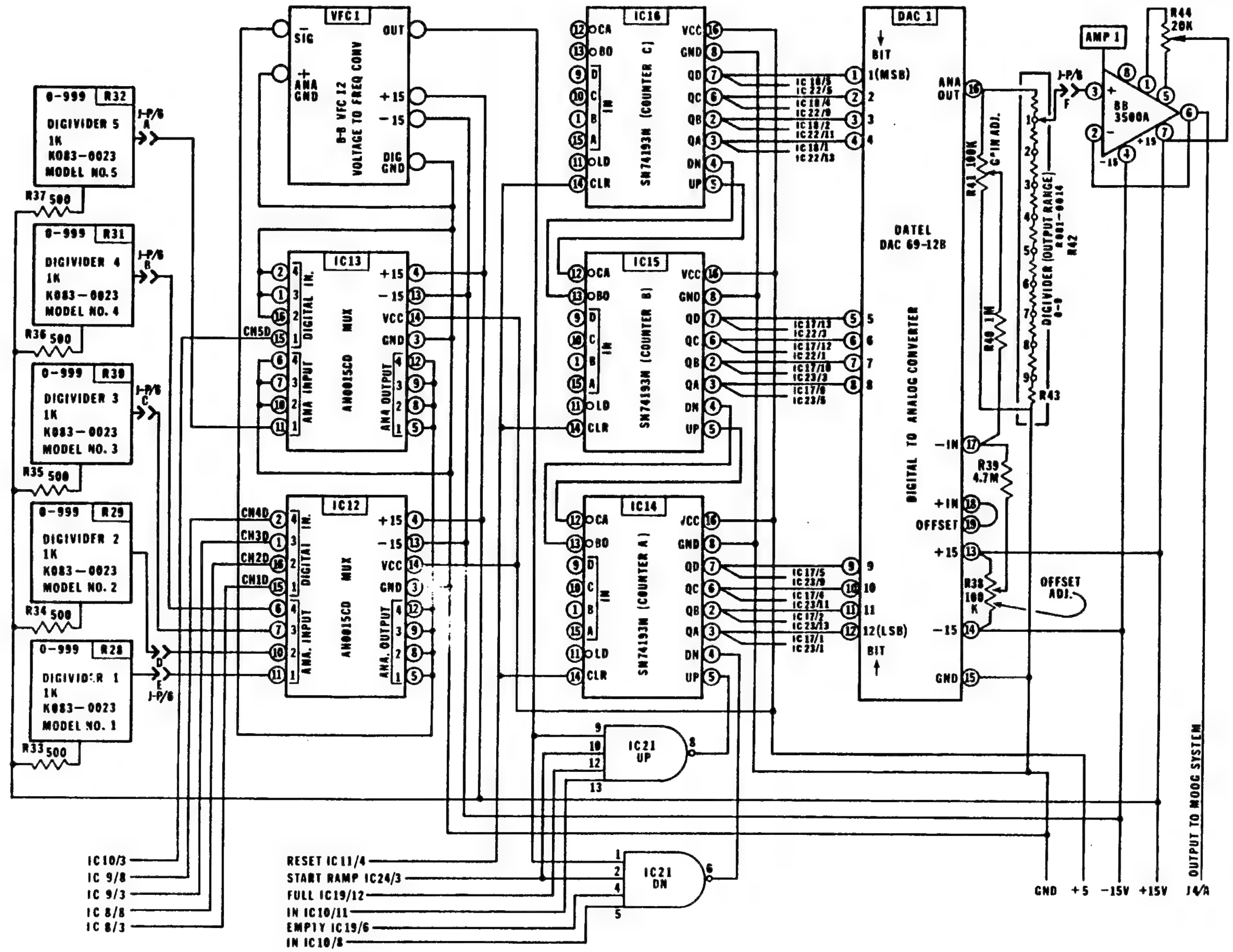


Figure 32: RAMP GENERATOR SCHEMATIC (Sheet 2 of 3)

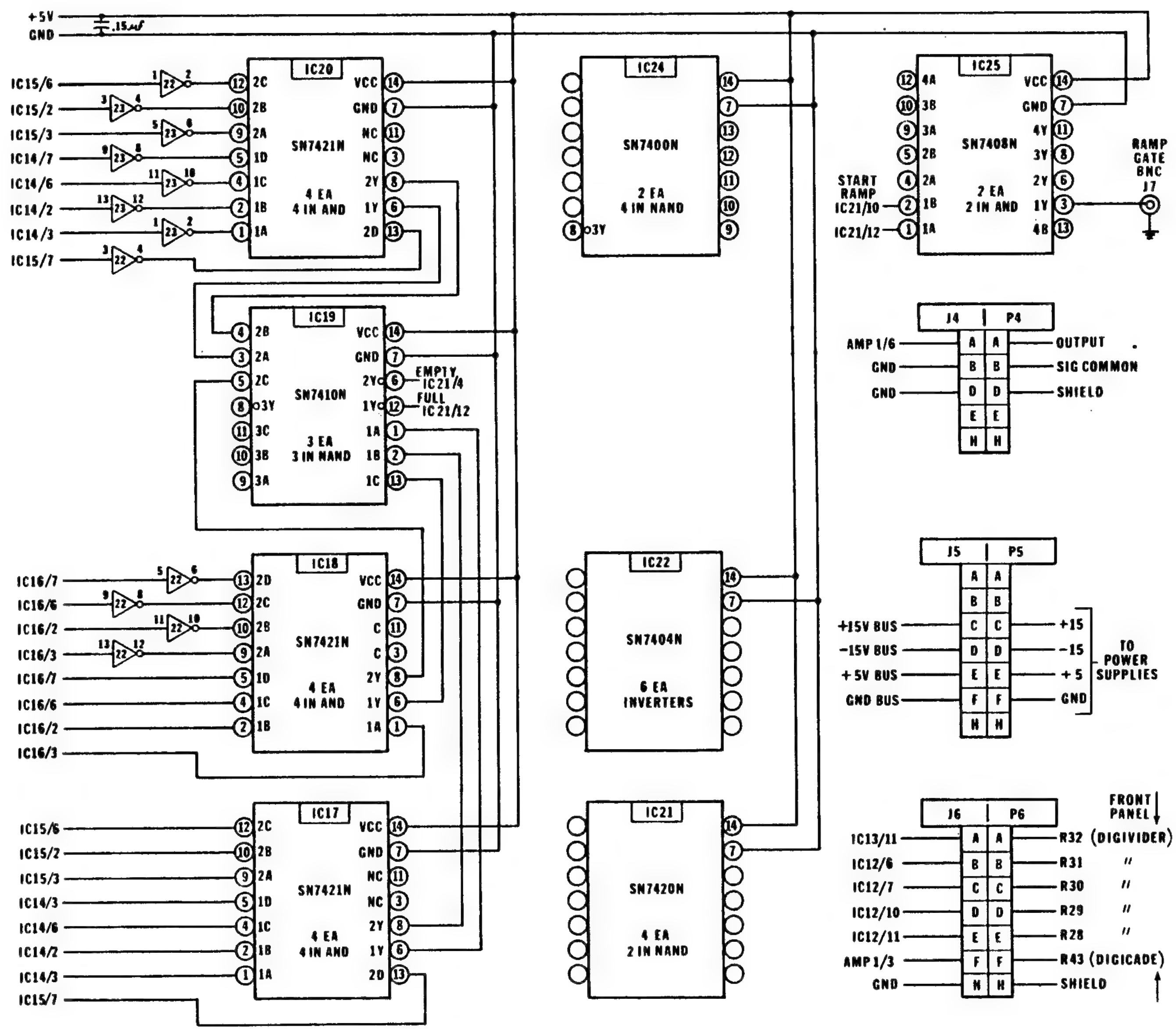


Figure 33 RAMP GENERATOR SCHEMATIC (Sheet 3 of 3)

APPENDIX E

SET-UP OF RAMP CONTROL

1. From the run sheet, determine the time needed to ramp each of the models from the rear position to the forward position. Time (sec) = $\frac{\text{distance (in)}}{\text{velocity (in/sec)}}$. Record on data sheet 5.

2. Using Figure 34 and the time needed to ramp forward, determine the dial setting for each model. Set each dial and record on data sheet 4.

3. It takes approximately 1.25 volts of ramp to move a model 1 inch. From the run sheet, determine the maximum distance that any of the models has to be ramped. This determines the maximum required ramp voltage. For example: 1 inch = 1.25 volts, 2 inches = 2.5 volts, 3 inches = 3.75 volts and 4 inches = 5 volts.

4. The range switch divides the ramp voltage output. A range setting of 9 means a 10 volt maximum output. 8 = 9 volt maximum, 7 = 8 volt maximum, ..., 0 = 1 volt maximum. Set the range switch at the lowest value which is still higher than the maximum required ramp value. Record the range setting on data sheet 4.

5. Set the rear position for all models to be ramped using the normal position potentiometer.

6. Using the manual ramp switch turn on one ramp control relay at a time to ramp a model forward. When the model has stopped moving forward adjust the ramp control potentiometer of the appropriate servo amplifier for the correct forward position setting.

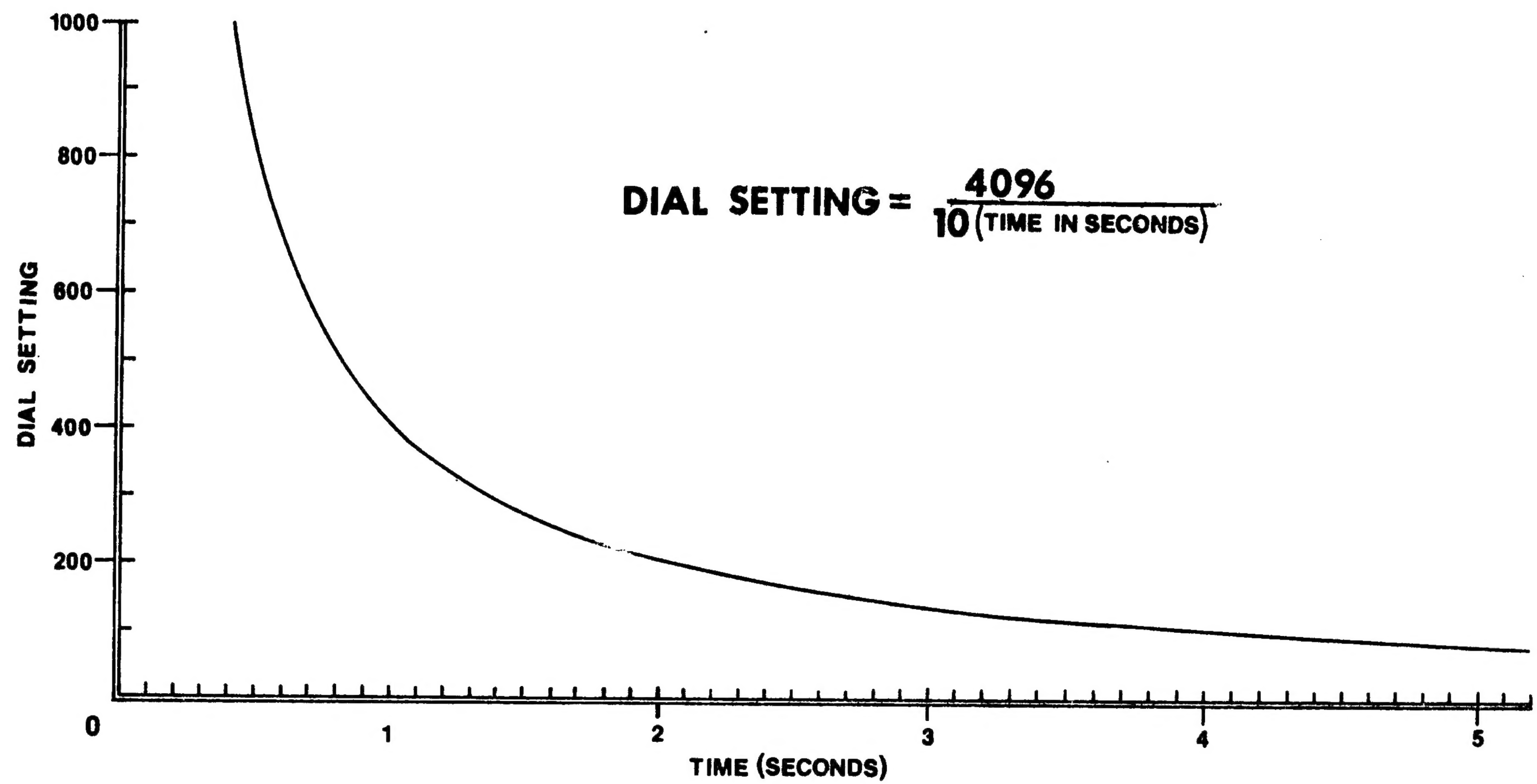


Figure 34: RAMP TIME vs DIAL SETTING

7. Check to see all requirements are set-up correctly by operating each ramp manually and recording the data on the #4 oscillograph.

APPENDIX F

AXIAL POSITION READOUT SYSTEM

It is necessary that the axial position of the model with respect to the arc heater nozzle exit plane be indicated on a continuous basis. The axial position read-out system (see Figure 35) was installed to perform this function. The position information is displayed at the master control unit cabinet by means of a panel mounted digital voltmeter. The position information is also recorded on a data computer and oscillograph.

An eight inch dual linear potentiometer is installed as a component part of each of the five axial positioning units. The dual potentiometer has two separate potentiometers mounted in one case with the wipers tied to one sliding rod. One of the potentiometers is used to provide the feedback signal for position control, while the other is used for position readout. The axial position readout potentiometer is connected in a conventional bridge configuration. The bridge termination and excitation voltage is supplied by the use of bridge signal conditioners. The bridge conditioners in use are a part of the facility and model instrumentation system. The DC amplifiers are also a part of the facility and model instrumentation system. The output signals from the DC amplifiers are connected to the facility patch board so that the signals may be patched to the various recording and display devices. Detailed information such as wiring, bridge conditioning equipment, etc., is documented as a part of the facility and model instrumentation system and is therefore available from this source.

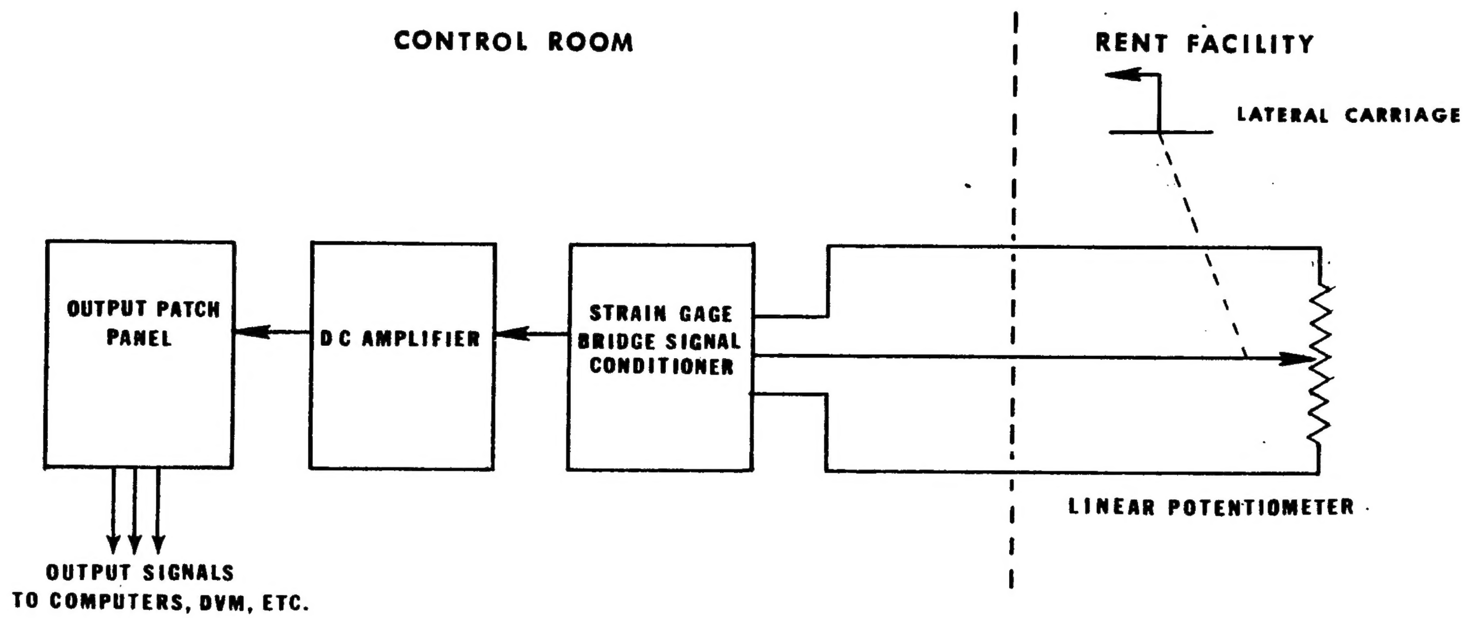


Figure 35 BLOCK DIAGRAM AXIAL MODEL POSITIONING READOUT SYSTEM